1952

Inheritance and interrelationships of some maize ear characters

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INHERITANCE AND INTERRELATIONSHIPS OF SOME MAIZE EAR CHARACTERS

by

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A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Genetics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

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Signature was redacted for privacy.

Dean of Graduate College

Iowa State College
1952

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INTRODUCTION AND HISTORY OF PROBLEM

The efficiency of any plant breeding program is enhanced if cognizance can be and is taken of easily noted characters partially or completely concomitant with those of economic desirability. Economically it is a small matter whether or not the association of traits is strictly genetic or biochemical. The fact that it exists is the important consideration. In maize breeding, until recently, the sole criterion for desirability has been yield. Any trait of plant or ear which would increase yield automatically became a desirable trait.

In Iowa, during the period of 1910 to 1930, pathological surveys showed the hitherto unrealized importance of ear parasitizing fungi which, through subsequent impairment of germination and seedling vitality, reduced the yield of the open pollinated varieties extant then. Among these was a sporadically occurring, weak parasite classified then as Basisporium gallarum Moll. but later more properly denoted by Standen (26) as Nigrospora oryzae (B. and Br.) Petch. Durrell (5) first noted this as an important ear and seedling disease of maize in Iowa in 1925. Reddy (14) followed with a study in which the pH of water extracts of maize cob meal was discovered to be negatively

correlated with apparent resistance to Nigrospora oryzae infection. This variation in acidity was further investigated among cobs of different inbred lines of dent corn and found to be genetic in nature. There was less variation in pH among cobs within an inbred line than among cobs from an open pollinated variety and there were distinct and measurable differences in pH between mean readings of inbred lines. All of these findings made before 1930 were finally reported by Reddy (15) in 1933.

The presently reported research falls into two sections naturally both from the point of chronology and of aim. It was originally started in 1930 as a genetic study in the disease resistance of Zea mays L. to infection by Nigrospora oryzae (B. and Br.) Petch. Even though no method of artificial field inoculation was known and the natural infection was extremely sporadic, it was thought that a study of inheritance of maize cob acidity would reflect the picture of disease resistance accurately enough. In the material used in the first year of that study additional, apparently negative correlations were found between pH and midcob color and between pH and resistance of the cob to bending to the breaking point. This is defined mechanically as the ultimate bending stress. Simultaneously collected data on these characters showed the associations to be real and confirmed the association of pH and disease resistance.

Brief summaries of part of these data were reported from 1932 to 1934 (9, 16) and the 1932 summary was quoted by Reddy in his later publication (15). More details of some of these earlier studies are given and discussed in this report.

The second phase of this problem covered the crop years of 1949 through 1951 and was concerned with the interrelationships of pH, midcob color, breaking strength and other ear characters and their combined effects on yield. Eleven of the intervening years were spent in the development and administration of a sweet corn (sugary maize) breeding program for a commercial vegetable seed company. During that time the traits of midcob color and breaking strength were satisfactorily incorporated as criteria in the breeding program. While this adaptation was, for the most part, of an observational nature, the results were very instrumental in establishing the approach and boundaries of the second phase of the research being reported here.

REVIEW OF LITERATURE

The scope and diversity of the present research suggests that a topical review of pertinent literature would be preferable.

Recent Occurrences of *Nigrospora*

The endemic nature of this global parasite is frequently overlooked since epiphytotics of it on maize are heavily dependent on a rather exacting complex of environmental conditions. Combining this with its inconspicuity tends to minimize its relative importance when considering only published reports of its occurrence. Standen (25) reported 42 per cent infection in 182 arrested axillary shoots and secondary ears examined in Iowa in 1937 when the estimated crop loss was *ca.* one per cent. In 1938, a year of more general infection, examination of over 1500 arrested axillary shoots among inbred lines and single crosses at Ames, Iowa, and open pollinated varieties from eight different localities showed infection rates averaging from 66 to 81 per cent. He concluded:

> It is obvious that such extensive infection of arrested axillary shoots and secondary ears insures abundant inoculum adjacent to a large percentage of the primary ears. (25, p. 657)

Personal observations for the crop seasons 1930 through 1932 in Iowa, for the seasons 1933 through 1943 in Connecticut, and for 1949 through 1951 again in Iowa confirm Standen's report and opinion. Possible reasons for an apparent increase in occurrence will be discussed later in this paper.

Standen (30) has recently reported finding it on maize in Venezuela and was able to observe spore discharge from the bulbous sporophore. This is the first observance reported for this phenomenon. Coated slides, placed at varying distances of 3 to 20 millimeters from specimens, received a sprinkling of spores in a 20 minute period. Muller (12) reported its occurrence on maize in Guatemala, although he lists it as N. sphaerica. It is listed by Ullstrup (32) as a minor parasite in Indiana in 1949. Buckholtz and Wallin (3) gave a brief summary of reported research on this disease at the Iowa station. Roane (18) noted the presence of N. oryzae in the complex of fungi isolated from broken stalks of maize in Virginia in 1950 and listed this species along with Gibberella zeae, G. fujikoroi, and Diplodia zeae as responsible for the major losses in maize in 1948 and 1949 arising from stalk, ear, and root rots. Marsh et al. (11) reported the genus Nigrospora among others as occurring in association with anthracnose tight lock of cotton bolls whose chief causative organism has been determined as Colletotrichum gossypii.

Andrews and Janes (1), in reporting on the heavy occurrence of stalk breakage in Michigan in 1949, considered a Fusarium sp. as chiefly responsible but noted Nigrospora spp. in some stalks. This peculiar association of Fusarium and Nigrospora was continuously noted in the 11 years of personal observation in Connecticut and numerous attempts to isolate Nigrospora strains from various lots of 1933 diseased material failed because of overgrowth of Fusarium moniliforme on the plates. This association was considered peculiar because on ears infected by both species, F. moniliforme would make the more effusive mycelial growth although N. oryzae would appear to cause much more physical damage through retting of shank and cob.

pH and Disease Resistance

Although pH of plant juices has been studied extensively for years and has been excellently reviewed and integrated by Small (23, 24) in his two monographs, very little evidence has accumulated for any association of pH of any plant parts with resistance to any disease. Reddy (15) quotes the English summary of the Russian work of Tropova (31) which indicated that varying pH values of different organs of the same plant would explain the differential susceptibility of the various organs of the host plant and might also

account for the differences in resistance of various selected strains.

From Hurd's data and descriptions (6) it could be inferred that some relationship between the pH of maize plant sap and disease incidence might exist, since she found in testing ten 1-year inbred strains of Reid's Yellow Dent from Indiana that a negative correlation existed between pH of seedling and young plant expressed sap and vigor of growth. This was a plant-to-plant variation and was not dependent on genotype. However, no further work has apparently been done on this topic.

Reddy (14) was the first to observe the negative correlation between pH of a water extract from healthy cobs and resistance to Nigrospora oryzae. His series of reports, previously cited, showed ranges in pH of these extracts from 4.4 to 6.3 with distinct differences occurring between means of inbred lines. These differences were noted both in open pollinated varieties and in inbred lines and a threshold point of susceptibility was determined to be in the region of pH 5.0 to pH 5.3. In one of these reports on inbred lines he noted that no diseased ears were found in lines averaging pH 4.7 or lower while nearly half the ears in lines averaging pH 5.9-6.3 showed the presence of Nigrospora oryzae.

Midcob Color

In a study on characters in corn correlated to yield, Winter (34) reported an association of color of the ligneous portion of a cob cross section from seed ears and the progeny crop from that seed. As far as is known, this is the only report of the genetic correlation of midcob color with yield. He classified the seed ears of five open pollinated selected strains of maize on the basis of four midcob color classes: pink, red, brown, and black, and noted that only two black ears were found. Percentage of seed ears of each of the four midcob color classes is given by strain with the average yield of the subsequent crop for each strain. Although there is nothing in this report to indicate that yield studies were made on an individual ear progeny basis, or even on a midcob color class basis, the correlations between midcob color classes of seed ears and their progeny yields are listed as: pink midcob, 0.79 ±0.11; red midcob, 0.60 ±0.19 and brown midcob, -0.74 ±0.14. It was noted that the significant negative correlation between brown midcob color and yield might be indicative of a pathological condition, but that no evidence was seen for it. All of these colors except black were considered to be inherent traits.

Demerec (4) must be credited with the first report of

midcob color as a genetic trait. His report, dated a year later than Winter's study, does not mention Winter's work and was probably based on research done during the same period of time but in a different section of the United States. Although distinctive colors were noted in different inbreds used in this study, the conclusion was rather dogmatically stated that colored midcob was a monogenic dominant over colorless midcob. Four midcob color classes are listed as: light pink, red, carmine red, and dark sepia. F_2 progenies from three crosses of colored x colorless and one cross of sepia x red all gave amazingly close conformance to expectation, the more so when it was noted that two additional progenies gave 35 red, 11 variegated, and 2 white midcobs. The variegated pattern was described as consisting of an interrupted ring or band of color around the pith. This is obviously a color pattern factor and not a shade or tint condition. Consequently on the basis of color vs. no color the above progeny must be classified as segregating 46 colored : 2 colorless. This is hardly a monogenic segregation.

Demerec also reported concordance studies of this factor with external cob color. Eight backcrossed progenies involving the two pairs of characters indicated independence of the two loci, red vs. white external cob color and red vs. white midcob color. It was further noted that a genetic

strain of aa constitution, which showed the brown external cob color typical of this recessive phase of the anthocyanin plant color locus, possessed red midcobs. This indicated differential interaction from that found between the A locus and the external cob color locus, P.

Nothing further has been done on this trait to establish its linkage relationships or its possible biological effect.

Breaking Strength

Breaking strength of the corn cob can best be defined as the ultimate bending stress of the cob. This has been measured as pounds of force necessary to produce the cross sectional fracture.

Winter (34) is the only one who has published any results on this subject. Winter noted that an unnamed Illinois farmer and seedgrower in 1920 separated the seed ears of his selected strain of open pollinated maize into two lots. One lot came from ears whose cobs had a breaking strength of 60 pounds or more and the other lot was composed of seed from cobs with breaking strength of less than 30 pounds. Progeny yield per acre from the higher breaking strength lot of cobs was greater than from the softer cobbed lot. Winter made a detailed investigation of breaking strength in relation to yield with five strains of open pollinated corn

being tested in Illinois. This same material was apparently used in his midcob color study mentioned above but no comparisons were made between midcob color and breaking strength.

Breaking strength was measured with the cob in the horizontal position using a self-recording tensiometric device. A 4-inch midsection of the cob was used with the break occurring at or near the center of this 4-inch piece. Average breaking strength of cobs from seed ears of a particular strain was tabulated with progeny yields in bushels per acre. These associations are shown for the five strains and a correlation table indicates that a correlation between breaking strength of parental cobs and progeny ears of 0.77 ±0.12 was found. Correlation of cob diameter in centimeters and breaking strength of the parental cobs was significant at a value of 0.73 ±0.14, while the correlation between parent cob diameter and progeny yield of 0.23 was nonsignificant. Error terms associated with these correlations are presumably probable errors rather than standard errors.

The deleterious effect of inbreeding was shown from a comparison of a parental cob mean breaking strength of 89.5 ±3.12 pounds based on 100 ears with the single year selfed progeny of these ears where an 80 ear sample gave a mean breaking strength of 65.9 ±3.45 pounds. This would not be considered an adequate comparison at the present time be-

cause of the obvious confounding effects entering into the comparison of these two means.

Interrelationships of Plant and Ear Characters and Yield Applicable to This Study

In the present report correlations existing among the following traits: length of cob, diameter of cob, breaking strength of cob, weight of cob, silking date of plant, and kernel weight or yield, were studied in conjunction with the multiple correlation of all of these considering yield as the dependent variable. Only examples of similar nature will be included in this literature review.

Keller (8) and Shaw (21, 22) have adequately reviewed the literature on this subject. Almost all of this data was collected on open pollinated varieties. In general, correlations of length and diameter of ear and diameter of cob were found to be positively correlated with yield. They were not always significant correlations, and, even when significant, were too small to be useful in prediction of yields. Silking date is usually negatively correlated with yield and is seldom of much magnitude.

As noted above, Winter found high significant correlations of breaking strength and midcob color with yield and a high significant correlation of cob diameter with breaking strength, but a low nonsignificant correlation existed between cob diameter and yield.

All of the above correlations were obtained in open pollinated varieties. Jenkins (7) made an extensive correlation study of many characters among inbred lines, among single crosses, and between midparent averages and progeny. These were based on plot means. Within inbred lines highly significant positive correlations of ear length and diameter with yield and a highly significant negative correlation of the date one fourth of the plants silked and yield were found. Within single crosses all three of the above characters showed correlations with yield which were highly significant and positive.

These differ from the results being presented here because they are correlations of means rather than correlations based on individual ears. A direct comparison of these two types of correlations is presented later in the present study.

MATERIALS AND METHODS

Here, too, a topical presentation is being made because of the diversity both of materials and of methods which were employed.

Strains of Maize Used

The strains initiating this study consisted of nine white dent and one white flint inbreds with all their single cross combinations. The inbreds were four to eight year selfed lines from the varieties: Silver King, Four County White and an unknown white flint strain. They were supplied by Dr. H. T. Jenkins from the Iowa stocks and had had extensive disease incidence notes taken on them during their period in the breeding nursery. Hot, dry, southwest winds during the pollinating season of 1930 made the success of hand pollinations very hazardous. Of some 1500 pollinations attempted only one well filled ear resulted. A similar condition existed among open pollinated ears which silked during that hot dry period. Advantage was taken of this situation to study cob pH variations with relation to disease incidence and amounts of kernels developing. In addition, open pollinated ears of all of Dr. E. W. Lindstrom's dent inbreds in the Genetics Department nursery

and some of the better yellow dent inbreds from Dr. Jenkins' nursery were harvested for pH studies. As a result of these preliminary studies, shifts were made in the inbreds used to exclude inbreds extremely susceptible to fungous parasites other than Nigrospora oryzae and to include some yellow dent, red cobbed inbreds. These newly included inbreds were derived from the varieties, Walden Dent, Proudfit Yellow Dent, Iodent, Osterland Yellow Dent, and Black's Yellow Dent.

These strains formed the basis of the disease studies made as well as the basis for pH, breaking strength, and midcob color research which was carried on. Progenies grown consisted mostly of backcrosses but some data were automatically accumulated on the parental inbreds, F_1's, and F_2's. These stocks were grown at Ames, Iowa, in 1931 and 1932 and at Milford, Connecticut, in 1933.

Mr. F. D. Richey, at that time in charge of all the Purnell corn breeding projects, kindly supplied seed of the double cross from the Arlington Farm collection known in 1930 as "Cross 48" along with seed of the four inbreds and two single crosses involved as parents. Unfortunately, both single crosses and three of the inbreds were completely destroyed by either ear and tassel smut caused by Ustilago zeae or by Diplodia ear and stalk rot caused by Diplodia zeae when grown in 1931.

When this study was resumed in 1949, none of the lines used previously were readily available. Consequently, two new sources of material were used. Dr. S. N. Smith, Research Director of the Michael-Leonard Seed Co., furnished seed of inbreds from his extensive nursery and allowed pollinations to be made in his field. He also advised in a selection of lines which would cover a wide range of maturities and cob breaking strengths. Consideration was also given to the geographical sources of the background to include as much potential genetic variation as possible. The final selection of 15 lines consisted of: 3 sweet, 11 dent, and 1 popcorn types. The range of variation for the characters studied here can be seen in Tables 30 through 32 which give the inbred means of the 1951 crop for all characters and all inbreds included in this later study.

Seed of these 15 inbreds, part of them at two dates of planting, were included in the Genetics Department nursery in 1950 and all possible combinations of all fifteen lines were made. The attempt was made to get all reciprocal crosses as well, but the popcorn inbred, having Jap Hulless variety blood in its background, had unfortunately carried through some of the sterility alleles found in that variety and only four of the fourteen possible combinations could be obtained. All fourteen combinations were obtained with this popcorn inbred as male parent. Seed of these inbreds

and single crosses was included in the 1951 studies as the "SNS" group of inbreds and hybrids.

In addition to this material Dr. G. F. Sprague, Professor in Agronomy, Iowa State College, collected ten ear samples from each single cross hybrid combination used in his 1949 single cross experimental tests which were planted in the same twelve fields throughout Iowa as were used for the 1949 Iowa corn yield test. These ten ear samples were drawn at random from a larger 45 ear sample which is a combined sample from the three plots of each hybrid at a location taken for moisture determination at harvest. The samples were placed in small open mesh bags, five ears per bag, and stored for drying in a convenient place at each farm. Personal visits were made to every farm in mid-December 1949, all samples were shelled with a portable hand sheller, and the cobs were brought back to Ames where they were stored at room temperature until processed. These data were intended for genetic analysis of hybrid combinations of a given number of inbred lines. After all the required data were collected and assembled for tabulation, it was seen that excessive nonorthogonality and many missing cells existed in the tabulations. The data were restricted to allow favorable conditions for statistical computation. As often happens in such cases more than two thirds of the data had to be forgotten and statistical analyses eventually made

on records for the 54 hybrids common to the six experimental field locations in the southern half of Iowa. These 54 hybrids represent all but one of the possible combinations of 11 inbred lines. These 11 inbred lines consist of 6 standard and well-known yellow dent inbreds and 6 new lines on which Dr. Sprague is investigating the combinatorial prospects.

These 11 inbreds and their single crosses were all included in the 12 inbreds with 65 of their possible 66 single cross combinations used in the 1951 studies which was designated as the "South Central" group of hybrids. For further comparison an additional 12 inbreds and their 66 single cross combinations called the "North Central" group, were also studied in 1951. All of these small lots of seed were kindly supplied by Dr. Sprague for these studies. The "South Central" group represent inbreds and hybrids adapted to the latitude of Ames while the "North Central" group are usually best adapted to the latitudinal region across the state which would be centered 50 to 60 miles north of Ames. Three of the inbreds and consequently three of the single crosses are common to both these groups. Experimental design and statistical methods of analysis will be presented for this 1949 and 1951 material in a separate section later.

Apparatus Used in Collecting Data and Methods Employed

pH determinations

Although two different methods were employed for determining pH, quinhydrone technique in the earlier studies and glass electrode in the later studies, the same methods were used throughout in preparing samples for the pH determination. Broken pieces of the center portion of individual cobs were ground in the same Wiley mill used by both Reddy and Standen to a fineness to pass either the medium or coarse screens with which that mill is equipped. The coarse screen was used only during the periods while replacement of the medium screen on its frame was being made and would amount to less than 10 per cent of the total grinding time.

The solutions for testing were prepared in small graduate cylinders known as milk graduates. These are calibrated with a single line at 10 cc. but hold between 15 and 20 cc. Aliquots of the ground cob meal were poured into the graduates to a depth of 2 to 3 cms., the cylinders were filled with distilled water, thoroughly shaken and allowed to stand for at least 20 minutes before reading. With the quinhydrone technique, a small excess amount of quinhydrone was added after this preliminary soaking, the cylinder was thoroughly shaken again and allowed a few minutes to reach equilibrium

before reading. This additional step was not necessary with the glass electrode technique.

With Reddy's technique of colorimetric pH determination using a Lamotte color wheel, it was necessary to filter the suspension of cob meal and water before placing the test solution in the comparometer rack. The time involved in this extra step combined with the coarseness of reading permissible colorimetrically were the deciding factors for the electrometric methods employed in these studies.

For the determinations made from 1930 through 1934 a quinhydrone electrode method was used having a millivolt meter calibrated to tenths of millivolts. Appropriate transformation tables were made for conversion of the voltage readings to pH. To obviate serious temperature deviations, most of the determinations were made at night when temperatures of apparatus and solutions could be held easily between 15° and 20° C. All readings were made in duplicate and the average of the two voltage readings was used in entering the transformation table. Duplicate voltage readings seldom differed by more than 0.4 millivolts. Members of the Chemistry Department working with electrometric methods had devised a modification for the outlet or contact tip of the calomel half cell that reduced the use of KCl soln. and speeded up the rate at which determinations could be made. This consisted simply of grinding a suitably sized

nipple made from soft glass tubing over the outlet tip of the calomel half cell. This covering nipple kept the half cell from becoming poisoned by the test solution, allowed ample electrical contact through the ground glass joint and permitted the valve in the half cell to be left open all during the testing time. Such minor refinements in technique become very important when hundreds of samples are to be tested.

The glass electrode apparatus used in the later studies was a standard model manufactured by the Cambridge Instrument Company, Ossining, New York. This has an internal electrode as standard equipment but has an external dipping electrode as an accessory attachment. Because of the stages of radio-amplification included in the circuit, this instrument is more sensitive and the recording dials are calibrated in hundredths of pH units. Using the internal electrode requires filtering of all solutions; this was employed in ca. 1000 determinations on the 1949 material. Because of the total time required per reading when the suspensions were filtered, a dipping electrode attachment was procured and the remainder of the ca. 15,000 readings were made by dipping the electrodes directly into the cob meal suspension. Fifty paired comparisons of the two types of electrodes on cob meal suspensions as well as checks on buffered pH standard solutions at the time of changeover showed no detectable differences in measurement with the two types of electrodes.

Mention should be made of the crudity of preparation of the suspensions which was deliberate after comparisons of different concentrations showed a tremendous buffering capacity or other ionic equilibrium producing factor in the water soluble solutes from cob meal. This stabilization effect has been noted by Reddy and was checked in these studies both in 1930 for the quinhydrone apparatus and again in 1949 for the glass electrode instrument.

By a fortunate oversight, remnants of the cob meal samples from the 1931, 1932, and 1933 crops were still stored in the attic of the Genetics Laboratory building when this study was reinitiated in 1949. Samples which had originally given readings over most of the pH range were sorted out and checked with the glass electrode. In these checks ten separate readings were made on each of the selected samples and were repeated on the same aliquots after four to five hours. Agreement with the recorded readings from the early 1930's was very good and indicated: (1) that the dried cob meal samples had not deteriorated with storage, and that the quinhydrone and glass electrodes gave equivalent measures of pH activity; or (2) that changes in cob meal with storage as far as pH was concerned were equivalently balanced by variances in reading between the two methods. For the purpose of this study the former interpretation is preferred.

Breaking strength

Breaking strengths were obtained through modifying a horizontal testing device originally designed and built for stalk breaking studies conducted by Dr. M. T. Jenkins. Since no complete description of this testing machine has been published, two photographs, Figures 1 and 2, are included here. Figure 1 is a plan photo showing: the location of the self recording, horizontally mounted, 200 pound spring scale; the double slide arrangement with the three fulcrum points for holding the cob; and the chain, which connects the foot lever and the slides, leading over the pulley on the distal end from the scales. The two metal edged boards visible beneath the slide mechanism are solely for support of the slide. The center fulcrum plate of the slide mechanism was fabricated from half-inch aluminum alloy sheet after a number of wooden plates had sheared while pulling very hard cobs. The metric scale on the ruler seen nailed to the surface of the machine was used for cob length measurements. Figure 2 is a perspective photo which shows equally well the simplicity of the machine.

Since it was originally designed for stalk strength measurements, the outer fulcra were fixed at eight inches on centers. For cob breaking, white oak blocks were made to fit over these edges to reduce the overall length of the test piece to three inches. This did not change the center

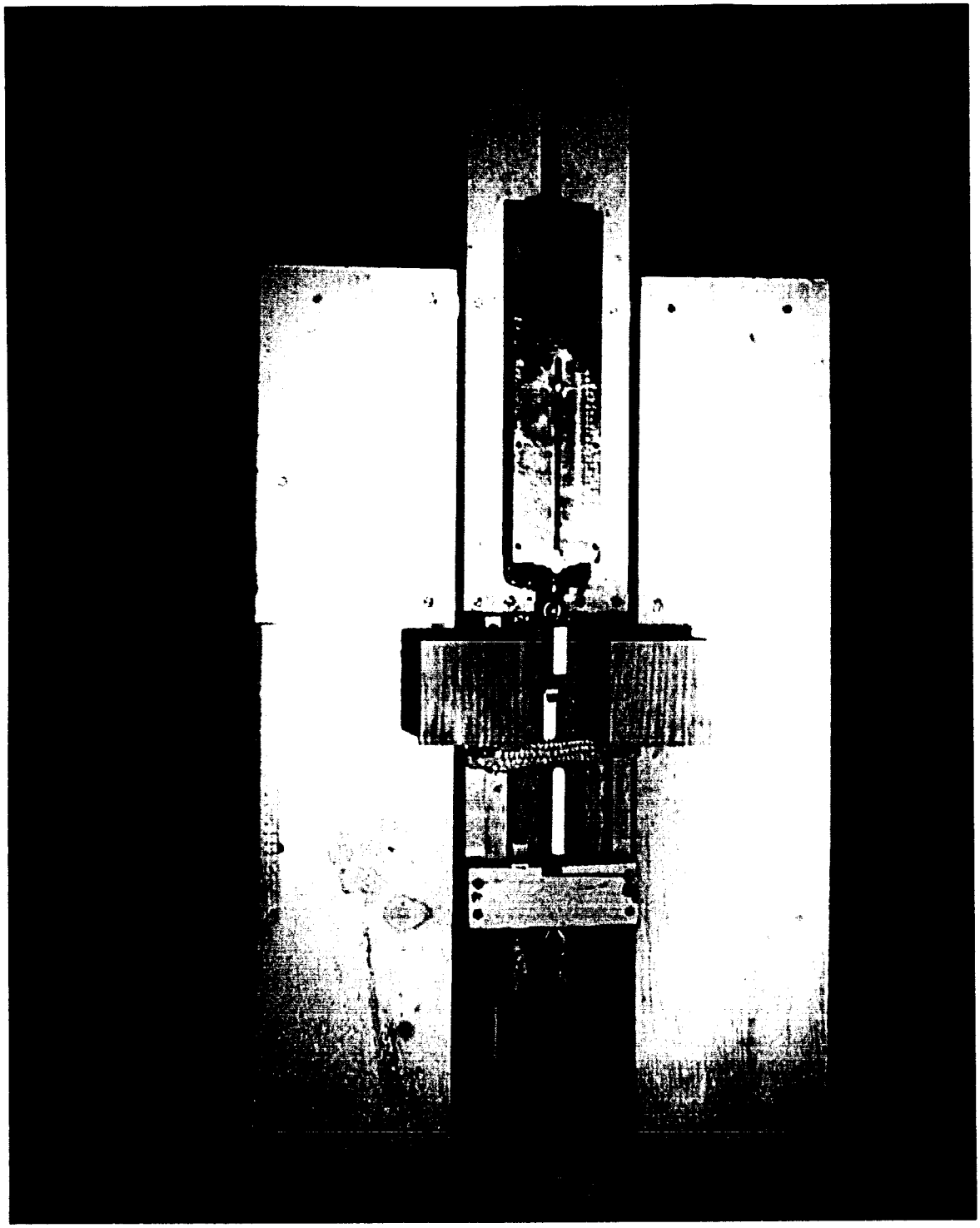

Fig. 1. [illegible] coil breaking machine.

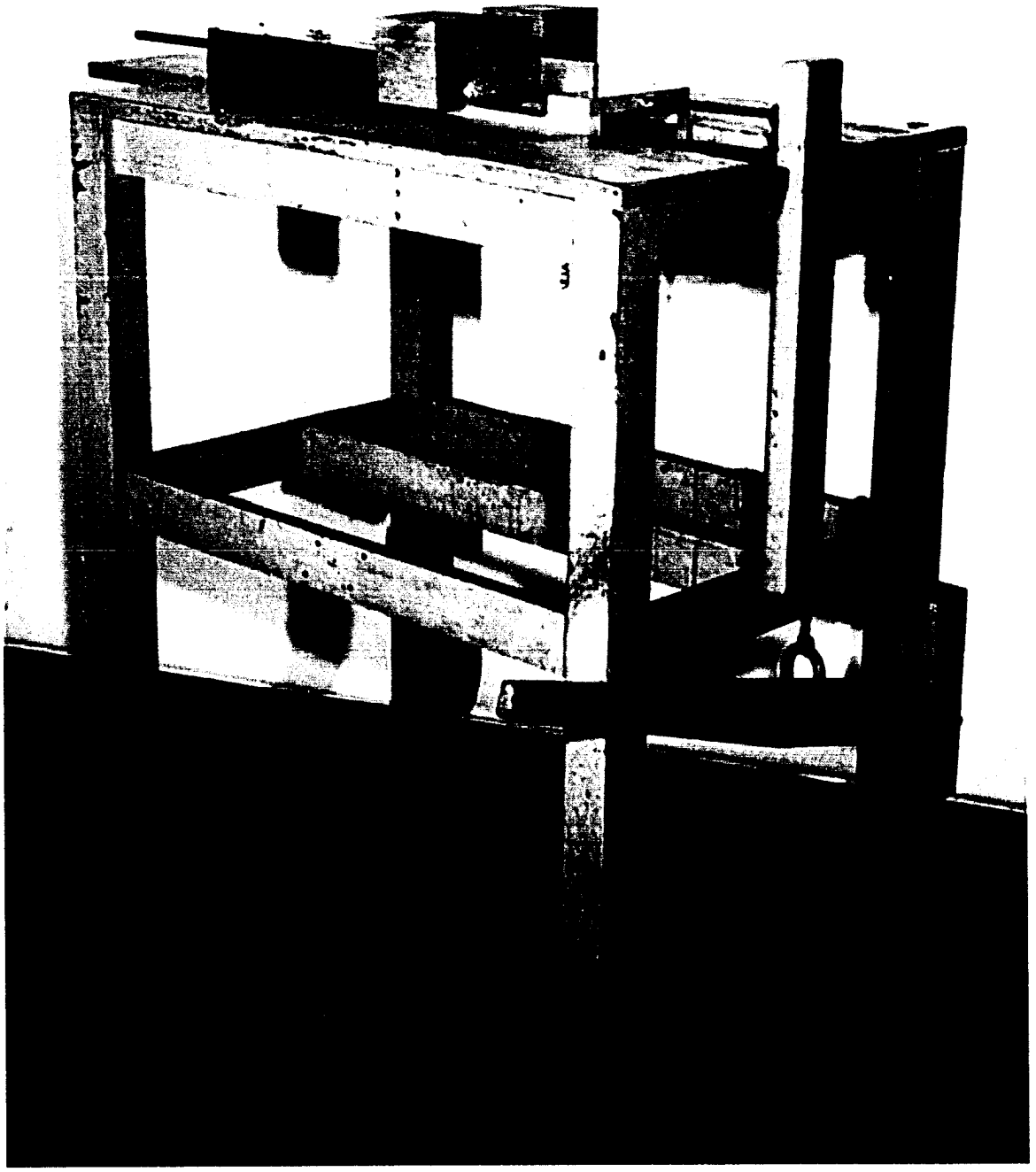

Fig. 2. Perspective photo of coal breaking machine.

fulcrum position or angle of attack. A cob, in place for testing, can be seen in both photos.

The procedure of getting the breaking strength estimate consisted of depressing the foot lever with steadily increasing pressure until fracture of the cob occurred. The loose needle on the scale was thus left on the calibrated face of the scale at the position attained when fracture occurred. The scale was graduated in 2 pound units and readings were estimated in 1 pound units. It was felt that the personal error in such estimates was sufficiently randomized and minimized considering the large number of readings made.

Cob length, cob diameter, breaking strength and midcob color grade were determined on each cob in one continuing complete operation. Lengths were measured in centimeters and diameters were measured in millimeters using a common sliding outside caliper such as can be obtained from any scientific supply dealer. Midcob color grades are explained below.

Midcob color

Only two reports have mentioned this character, the one by Demerec (4) and the other by Winter (34). Since Demerec's studies were made on inbreds, hybrids, and segregating progenies at Cold Spring Harbor, New York, and

Winter's studies were conducted independently on selected open pollinated strains of yellow dent corn at Urbana, Illinois, it is not surprising that agreement between the classification schemes of the two workers is poor. It is also quite probable that the material in these two studies differed considerably in expression of midcob color.

The large number of inbred ears examined in the winter of 1930/31, when the present study on midcob color was started, gave the opportunity of sampling a greater range of expression of this character than was available to either of the other workers. Therefore, the scheme of grading used in these studies is being explained in detail. Visual color grading and classification, being a completely subjective operation, must have fairly well defined class limits, must be simple in application, and must be easily demonstrable to others if it is to be of more than individual personal use.

It was noted in examining inbred ears that reds and browns appeared as distinct and separate colors in some inbreds and in apparent combinations as shades of maroon in others. The first notice of this character occurred in a white cobbed strain and appeared as a distinctive bright red ring. Without attempting to catalog the idosyncracies of expression found in cobs of different strains, a simple dichotomous key was based on the following:

color *vs.* no color

red *vs.* brown series

light *vs.* dark shades

For ease of recording and classifying and to allow for the presence of the combination of reds and browns since these colors were not mutually exclusive in the tissue, numerical values were assigned to the named color classes as shown:

00 - no color

10 - pink

20 - red

01 - tan

02 - brown

This scheme allows the numerical combinations of any grade of one series with any grade of the other. Thus, the pink plus tan colors in the same midcob can be numerically recorded as 11 and so on for other combinations.

Color descriptions are usually useless. For this reason the following table gives the direct matchings of the 5 colored classes of midcob with the swatches of color chart sources: M & P (Maerz and Paul), R (Ridgway) and RHS (Royal Hort. Soc.). Complete references to these sources are given under "Literature Cited." The color names and code letters and numbers follow the schemes used in each of the sources. Indication of more than one color swatch is used to signify to some extent the range of shades which would

Table 1. Midcob color comparison with standard color charts

Midcob color		Color chart designations		
Grade	Name	M & P	R	RHS
00	white	This is snow or chalk white -- not referred to charts		
01	tan	9G3 to 9H4	Light buff (XV-17'f)	
02	brown	14A8 to 14A9	Snuff brown to Vienna brown (XXIX-13"k or 15"k)	
10	pink	2D8 to 2F9	Venetian pink (XIII-1'f) Chantenay pink (XIII-3'f) Alizarin pink (XIII-1'd) Jasper pink (XIII-3'd)	
20	red	5E6 to 5H6	Jasper red (XIII-3') Acajou red (XIII-1'i) Pompeian red (XIII-3'i)	Cardinal red 822 Chrysanthemum Crimson 824
11	pink, tan	3D10 to 3G10	Congo pink (XXVIII-7"b) Japan rose pink (XXVIII-9"b) Onion-skin pink (XXVIII-11"b)	
22	red, brown	6L7 to 6L9 7L7 to 7L9	Madder brown (XII-3'k) Brick red (XIII-5'k)	Garnet Brown 00918

fall in one midcob color class. Both copies of Ridgway which were available showed some foxing, flecking and erosion of the color swatches. Using the two copies for comparison against each other and the cob sample should minimize errors here. Missing entries signify no suitable match.

It should be noted that the combined colors of pink with brown or of red with tan are either of extremely rare frequency or are too easily confused with other classes. In the 17 years of personal observation covering literally hundreds of thousands of ears, only a few were seen that could confidently be placed in either of the above categories. Perhaps an individual with better color perception would see these combinations readily. Also very rare in occurrence were black midcobs such as mentioned by Winter (34). Upon examination of a few of these with 12x to 20x pocket hand lenses no evidence of mycelia or spores was seen.

Some pigmentation in the center of the cob is frequently associated with fungal and bacterial infections. However, little experience is necessary to distinguish these colorations from the normal development of midcob color. Such discolorations are common as: diffused pink to red through tissue associated with Fusarium moniliforme infection, buff or grayish white associated with Diplodia zeae, yellow, tan, or brown bundle spots seen with Acremonium cephalosporium and a diffused pale yellow in dried cobs after infection by

Phytomonas stewartii. Of course, there is the gray or black appearance in ears badly infected with Nigrospora oryzae arising from heavy sporulation of the fungus, but at this stage the cob is usually so badly retted that it fragments very easily.

Ear and cob weights

In the 1951 material all individual ears were weighed after drying, shelled, and then cobs were weighed. The difference of these two weights thus becomes kernel weight or yield. Obtaining kernel weight in this manner is much simpler than shelling individual ears and weighing the shelled grain directly. Errors inherent in this inverted procedure must be very slight.

In the group of SN3 hybrids grown in 1951 the inclusion of su su inbreds necessitated an adjustment of kernel weight data for all hybrids involving the Su Su x su su or su su x su su combinations. This was done because starchy kernels are known to be heavier than sugary kernels in all cases where both occur together on a segregating ear. The procedure used was as follows:

1. visual estimate of the percentage of sugary kernels on an ear was made based on preliminary counts to standardize the estimate;

2. a composite sample of mixed kernels from the three ears in a hill was taken from the center portions of the ears at the time of obtaining ear and cob weights;
3. two hills were sampled at random for each hybrid involving the Su su or su su genotype;
4. at a later time 50 Su and 50 su kernels were chosen at random and weighed on a small torsion balance to the nearest half centigram;
5. and proportionate ratios of Su:su were calculated and incorporated into an analysis of variance to confirm the homogeneity of the calculated ratios in as far as variance due to particular inbred parents or specific hybrid combinations was concerned.

After determining the validity of the adjustment ratio to be used, all kernel weights of segregating ears were adjusted to the equivalency of expected Su Su genotype for further studies. It was suspected that cobs of Su su and su su ears also needed corrections for cob weights and breaking strengths which could be directly assigned to the biochemical activity of the su gene. This correction, to have any validity, would require a separate study of various backcrossed progenies and could not be included with the present research.

Ears and cobs were weighed on a Toledo table model scale having a capacity of 500 gms. with calibrations in even 2 gram units. Because these markings on the face of the scale were so close together, weights were read and recorded in the odd numbers which would correspond to the medial points between the calibration marks.

Silking dates

With all inbred, single cross, and other material incorporated into one large experimental block in the nursery in 1951, silking dates of all material are referred to the few plants which silked first in the area. These were all single cross plants and the day on which they silked was recorded as day 1. This occurred on 26 July 1951. No plant was recorded as being silked unless more than three silks had extruded. Since most silk extrusion occurs between the hours of 0000 and 1200 and since daily visits were made to all hills in the experimental area, errors in silking date record can be no greater than one day. These errors introduce an uncontrollable bias into the data; the occasional oversight errors which must inevitably occur also give bias in the same direction.

1951 plot layout

The main central portion of the 1951 experimental area

consisted of ten randomized blocks of the 328 single crosses and 36 inbred parents planted as single hill plots. To decrease interplot competition yet not interfere with the customary between-rows spacing of 42 inches in the nursery and to make all hills equidistant from each other, the scheme of hexagonal or "honeycomb" arrangement commonly used in orchard plantings was adopted. This allowed spacing hills farther apart, 48.2 inches between hills, while still retaining the 42 inch spacing between rows. To achieve equidistance between hills requires hills in adjacent rows to be staggered so that two hills in one row and the intermediate hill in the adjacent row form the apices of an equilateral triangle. With between-row spacing of 42 inches, the between hill spacings automatically become 48.2 inches, for these are halves of the minor and major axes of hexagons or altitudes and sides of equilateral triangles, respectively.

Individual hills of the 328 single crosses were planted in blocks of 16 rows east-to-west containing 21 hills each. The final eight unused hills in every block were planted with material of comparable vigor and maturity. The blocks of hybrids were arranged in two strips of five blocks across the experimental area and the ten randomized blocks of the 36 inbred parents were placed in a single strip between. To match the rows covered by the hybrid strips, inbred blocks were made as eight rows east-to-west having five

hills each; here too, the unused hills in each block were planted with comparable inbred material. A guard strip of inbred material two hills wide encircled the perimeter of the inbred planting with an additional two hills of hybrid material on the two sides next to the single cross strips. This central area of hybrids and inbreds was in turn encircled with border plots of hybrid material five hills wide on the east, south, and west sides, and two hills wide on the north.

1951 cultural notes

The three groups of single cross and inbred parent material used in this study were described in a previous section. Seed of the SNS group of hybrids and inbreds were planted at the rate of five kernels per hill; seed of Dr. Sprague's material containing the NC and SC groups of hybrids could only be planted at the rate of four kernels per hill. All seed was sludge treated with a commercial seed treatment formulation known as "Power Pak." When stand was ca. 8 inches high, all hills containing more than three plants were thinned to leave the three most vigorous plants. Hills containing three or less plants were untouched.

Mention must be made of the seed bed condition and general climatic situation through the crop season. Cold wet weather greatly hindered good seed bed preparation; one

corner was badly puddled and remained hard and almost impervious during the season. The broadcast application of fertilizer showed strip inequalities which were very noticeable in the plant growth. Both these items probably contribute most of the significant variation due to replicates which can be seen in the analysis of variance tables of the results.

The consistently below normal weather through the entire growing season can be seen in Table 2. This shows the average weekly temperatures and rainfalls with the 1951 weekly departures. These data were kindly supplied by Drs. R. H. Shaw and G. L. Barger, Assistant Professors of Climatology here at Iowa State College, and were derived from unpublished records and summaries and from Dr. Barger's Ph.D. thesis (2). All data were collected at the weather station maintained at the Iowa State College Agronomy Farm situated about three miles southwest of the Genetics nursery.

These temperature and rainfall anomalies can easily account for the peculiar yield performances seen in the NC and SC groups of hybrids.

Table 2. Weekly Climatological Data, Ames, Iowa, ISC Agronomy Farm Weather Station
Lat. 42°0'N, Long. 93°39'W

Std.[a] Week No.	Month	Temperature Mean[b] 20 yrs.	Temperature 1951 deviation	Rainfall Mean[c] 53 yrs.	Rainfall 1951 deviation
10	May	55.4	-1.7	0.81	-0.33
11		59.9	-0.1	1.01	-0.17
12		66.0	3.7	1.08	-0.72
13		64.9	-0.3	1.04	-0.54
14	June	60.1	-6.5	1.35	3.18
15		64.6	-4.0	1.04	0.29
16		70.0	0.4	0.85	0.17
17		68.7	3.9	0.88	-0.22
18	July	64.9	9.7	0.92	1.31
19		69.3	-6.6	0.71	-0.05
20		72.6	3.4	0.78	0.02
21		73.9	2.1	0.64	0.16
22		74.4	0.9	0.94	-0.94
23	Aug.	71.9	-2.8	0.79	-0.01
24		70.4	3.0	0.93	1.07
25		66.4	5.7	0.74	0.73
26		71.1	0.5	0.91	0.31
27	Sept.	68.1	-0.9	0.80	-0.71
28		65.3	-1.7	0.91	1.88
29		59.2	5.8	1.22	-1.22
30		56.5	5.9	0.87	-0.61
31		59.4	0.5	0.78	0.31
32	Oct.	54.4	-2.3	0.57	0.71
33		57.3	3.7	0.47	-0.35
34		43.9	-6.4	0.44	0.62
35		42.9	3.8	0.53	-0.36

[a]Internationally Standard Climatological Weeks are numbered in 7 day periods with year starting 1 March.

[b]Weekly average (max. + min.) temperatures in °F., 1925 through 1944.

[c]Weekly average precipitation in inches, 1893 through 1945.

Harvesting was done by hand and harvest date was based on the silking date. Studies by Shaw (22) had shown that in spite of the differences between the climate of the 1947 and 1948 seasons maximum dry weight was attained in this area of the Corn Belt at ca. 51 days. Slight decreases in number of days between silking date and maximum dry weight attainment for earlier than average hybrids could be expected. Considering the abnormalities of the 1951 climate it was arbitrarily decided to pick the earliest maturing strains 57 days after silking date and gradually increase this as picking progressed to hills of later strains. Harvesting was completed on material which had then remained in the field from 75 to 84 days after silking. This completion time was also on the second day following the first killing frost. All material was transported to the greenhouse after harvest and dried there to an air dried condition of ca. 15 to 20 per cent moisture before weighing and shelling.

RESULTS

Interrelationships of Maize Ear Characters Observed from 1930 Through 1933

Variations in pH attributable to environment contrasted with variation caused by genetic background

Environmental factors considered here may be any factors influencing pH and not directly traceable to differences in plant genotypes. These would include differences in pH readings between:

1. two ears on the same plant regardless of pedigree,
2. ears of the same inbred or single cross in the same nursery row,
3. ears of the same inbred or single cross from adjacent rows planted at different dates,
4. ears of the same genotype showing different proportionate amounts of kernels on the ears,
5. healthy and diseased ears of the same genotype, regardless of the causal organism involved.

Tables 3 and 4 briefly summarize these results.

Table 3. Average pH differences in early vs. late planting of inbreds

Year	No. of inbreds compared	pH difference (late - early)
1931[a]	22	0.15 ± 0.050**
1932	12	0.15 ± 0.056*
1933	9	0.06 ± 0.014
Total	43	0.139± 0.038**

*significant at $t_{.05}$

**significant at $t_{.01}$

[a]1931-32 grown at Ames, Iowa; 1933 at Milford, Connecticut

Table 4. pH comparisons within inbreds. 1931 crop.

No. of strains compared	Comparison	Avg. pH diff.
13	Avg. (diseased-healthy)	.3846**
16	Avg. (poorly filled-well filled ears)	.4370**

**significant at $t_{.01}$

Some unusual relationships found in these studies are included below.

1. On two eared plants the top or first ear usually showed lower pH than the bottom or second ear. These differences varied in direct proportion to the magnitude of difference in size of the two ears. Small differences between ears would show negligible differences in pH readings; large differences would show differences up to 1.0 pH between the two ears.
2. Plant to plant variations in the same nursery row of inbred or single cross would be negligible. Strains of low average pH readings, 4.8-5.0, would have smaller range and error than strains of high average reading, pH 5.4-5.7. Correlation between mean pH and its variance was high.
3. Paired comparisons of early vs. late planting of inbreds were made in 1932 because it was the practice to alternate early and late plantings of all inbreds. The year 1932 was considered an exceptionally good year for maturity because of continuing warm weather and late frost date. Nevertheless, healthy cobs from the late planting still showed higher pH readings than healthy cobs from the early planting. These differences of means would usually be approximately 0.2 pH.

4. pH varies in almost inverse proportion to the "set" of kernels on the ear. All healthy inbred cobs, regardless of genotype, with less than 10 per cent kernels developing would be at the same pH level, about pH 5.8. This was checked on both poorly pollinated ears and on cobs which developed under shoot bags, i.e. were never pollinated. This indicates that the materials responsible for the pH reading found in healthy, well matured cobs develop in conjunction with the biochemical activity of ear development. This relationship can be localized within the ear when cobs of partially filled ears are examined. Cob tissue immediately under individually developed kernels in strains genetically hard cobbed and possessing midcob color will show lignification and midcob color only in the vicinity of the bundles forming the kernel attachment.

5. The varying effects of different fungi on cob pH is noteworthy. Increase in pH of cobs infected with Fusarium moniliforme is directly proportional to macroscopically visible degree of infection. Slight disease evidence would increase pH 0.1-0.2 units; badly infected ears having the mycelial mat dense enough to cement the husks to

the ear will show increases up to 1.0 pH depending on the genetic potential of the strain. In all badly infected ears, regardless of causal organism, the pH readings generally fall between pH 5.8 to 6.5.

Diplodia zeae infections showed a similar but more pronounced increase in pH. Mild infection created almost maximum changes in pH. The highest pH readings found were from cobs of ears severely infected with D. zeae, from pH 6.4 to pH 7.8.

A very few ears infected with a blue green spored organism, quite probably an Aspergillus sp., decreased pH markedly. The lowest reading was pH 3.8. In attempts to isolate Nigrospora oryzae, a similar unidentified Aspergillus sp. was occasionally found on the plates producing circular colonies 1.0-1.5 cms. in diameter. Crystallization in the substrate subtended by the mycelial mat was always noted in approximately two weeks after inoculation and the colonies were always in the vicinity of the inoculum. At that time the mixed culture of F. moniliforme and N. oryzae would be thoroughly

spread over the plate and through the substrate except in this area supporting the Aspergillus colony.

Nigrospora oryzae infections of different intensities produced an intermediate effect between those of F. moniliforme and D. zeae. Reduction in cob weight and structural strength because of retting is most noticeable with N. oryzae; severely infected ears of F. moniliforme and D. zeae produce similar weight and structural strength reductions presumably because of cob tissue digestion during fungus growth.

Relationships among midcob color, pH, breaking strength and disease

The red midcob color grades in the 1932 planting were consistently associated with changes in breaking strength of the cobs; cobs without red pigmentation being weakest, pink midcobs, intermediate, and red, strongest. This is in agreement with Winter's findings (34). The red series showed a similar association with pH. Cobs lacking midcob color were usually higher in pH than those having midcob color. The pH difference between pink and no color was greater than that between pink and red. The association of this red series with pH and Nigrospora incidence between

inbreds is shown in Table 5. A direct comparison is made between the average pH's in 1932 and the per cents of N. oryzae infection in 1931 in the same inbred by midcob color classes. The comparisons are made between two years' data because 1932 was a "good" corn year while 1931 was a "poor"

Table 5. Association of Nigrospora incidence in 1931 crop of inbreds with pH and midcob color readings from 1932 crop

Midcob color class -- Red series								
No color			Pink			Red		
Inbred	avg. pH 1932	% Nig. 1931	Inbred	avg. pH 1932	% Nig. 1931	Inbred	avg. pH 1932	% Nig. 1931
La	5.2	1.0	Cla	4.8	19.4	Ids	4.8	0.0
Ose	5.0	0.0				4Co63	4.7	0.0
Pr	5.2	0.0				Idt	5.1	5.3
Lo	5.0	14.8				Osf	5.0	7.0
Ldg	5.0	30.8				ide	4.8	36.0
Blx	5.1	37.5						
Bls	5.3	38.3						
Wal	5.3	47.9						
Mo	5.4	57.3						
4Co31	5.0	73.9						
4Co13	5.6	84.4						
4Co27	5.5	84.8						
WhF619	5.3	86.4						
4Co101	5.0	90.3						
Avg.	5.2	46.2		4.8	19.4		4.9	10.7

corn year but a "good" Nigrospora year. Only inbreds on which data for at least 20 ears could be obtained each year were included in this comparison. Unfortunately, only one inbred in the group could be considered as pink midcobbed

strain and it does not give an adequate or an accurate picture of this color class in the series. Its deviation must be considered as a sampling deviation since cumulative information indicated the intermediacy of this midcob color group in the pH and disease distribution. The general pattern of relationship of pH with H. oryzae is easily seen. This is the relationship pointed out by Reddy. The scatter in the distribution illustrates the variability of the difference between phenotypic potential and genotypic expression, the former generally being called the genotype while the latter is the observed phenotype.

Winter (34) devised an index figure, called the average stress value, breaking strength divided by the difference of the cubes of the external cob diameter and the diameter of the pith section. His breaking strength readings were the ultimate bending stresses of tubes rather than of solid rods. Since differences of two such values depended exponentially on tube-wall thickness, since uniform composition of tube walls was necessary for equivalence, and since pith diameter was seldom more than one third of the cob diameter, the correction for pith diameter was thought to be unnecessary in this study.

The correlations of breaking strength and diameter for all 1932 cobs was determined. All possible correlation differences between inbreds, between single crosses, and

between backcrossed progeny groups were tested for significance using Fisher's z transformation. No significant differences were found and the entire data were pooled. The highly significant correlation of 0.82 was found for this entire sample population of 1999 healthy, well filled and well matured ears.

An attempt was made to find some chemical fraction which would be associated with the breaking strength phenomenon. Composite cob meal samples of one soft cobbed, one medium cobbed, and one hard cobbed line were fractionated by a student, C. G. Caldwell, in the Chemistry Department. Fractions for the three strains are given in Table 6 as percentages of the total sample analyzed.

Table 6. Chemical fractions of maize cob meal of inbreds with varying breaking strength

Breaking strength	Hot HOH extract	Cold HOH extract	Difference (hot-cold)	Ether extract	Glucose
Soft	12.46	11.05	0.41	0.219	6.87
Medium	8.59	7.26	1.33	0.274	2.49
Hard	9.84	8.33	1.51	0.179	2.89

The only direct association found was in the percentage of material soluble in hot water but insoluble in cold water. No attempt was made to identify such materials.

Less ear disease of all kinds was found in hard cobbed

strains when compared with soft cobbed strains. In general, low pH lines were hard cobbed lines and vice versa although there were some outstanding exceptions. Progenies of hard cobbed lines seemed to have more drought tolerance and more overall vitality than progenies of soft cobbed strains.

All of these items pointed to the suggestion that consideration of this interacting complex of midcob color, pH and breaking strength could be useful in obtaining more efficient and productive types in a breeding program. Conversely, parental inbred selection based on high yielding progeny performance should automatically cumulate inbreds having greater active acidity, breaking strength and amount of midcob pigmentation.

During the 11 year period in Connecticut while actively working in commercial sweet corn breeding, observations were continually made on the last two of these characters. These personal observations confirmed the above opinion. The opportunity to check these interrelationships of yield and ear characters more rigorously was made available in 1949 and results from these recent studies are presented.

Interrelationships of Maize Ear Characters Observed From 1949 Through 1951

Study of ear characters in single crosses with relation to yield and field locations. 1949 crop.

Cobs of 54 single crosses obtained from six district fields in the southern half of Iowa (see Figure 3 for locations) were used to obtain correlations among the following characters: cob length, cob diameter, breaking strength, and pH. These correlations were determined within locations and for the total data. Means of the four characters for each hybrid in each field were calculated and these means were used for correlations of these traits with yield and kernel moisture content at harvest. Yields and moisture contents were average values for a particular hybrid at a particular location. The data for these latter two variates were kindly supplied by Dr. Sprague from his unpublished records on experimental hybrids.

Table 7 shows the numbers of individual items entering into each correlation, all correlations between individual ears by location and by total, and the corresponding correlations based on hybrid means. Correlations of these means with harvest moisture per cent and yield are the single entries in the two right hand columns of the table. Column and stub headings are abbreviated as follows:

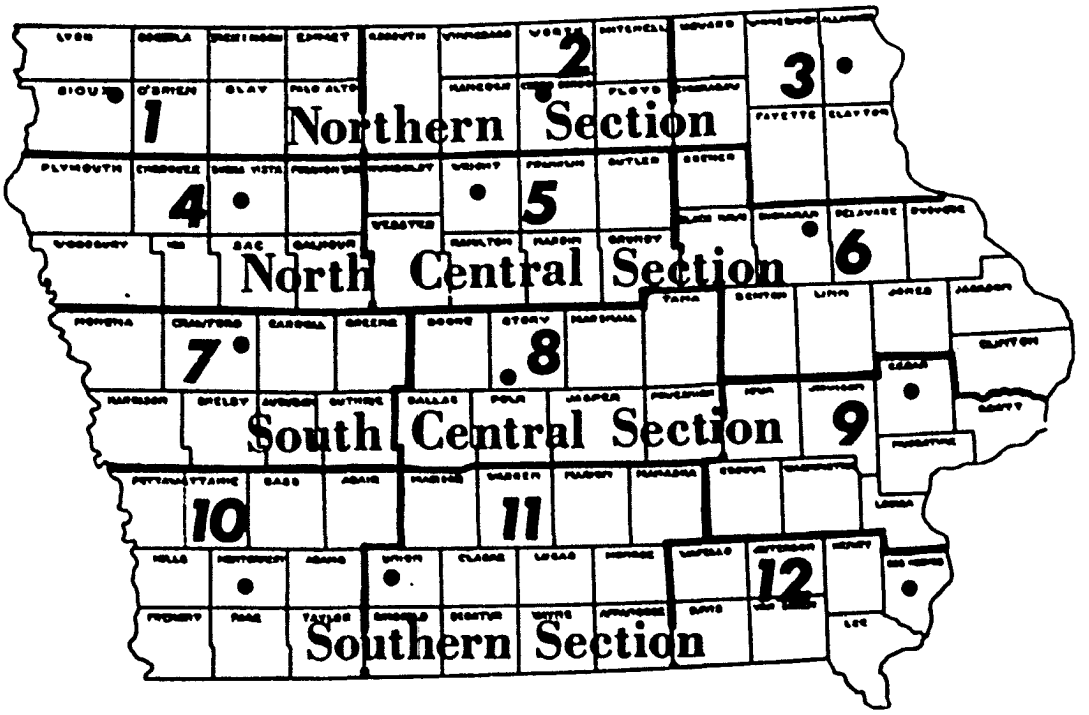

Fig. 3. Division of the state into sections and districts. Each dot shows the location of a test field. 1949.

Table 7. Ear character correlations by districts, totals and means - 1949 single cross data

Character	District	No. of ears	Character L[a]	D	B	W	Y
H	7	462	-.167**	-.165**	.038		
	8	501	-.195**	-.086*	.021		
	9	422	.006	-.247**	-.225**		
	10	448	-.118*	-.148**	-.065		
	11	473	-.075	-.175**	-.042		
	12	1235	.111**	-.173**	-.206**		
	Total	3541	.062*	-.235**	-.186**		
	Means	324	.206**	-.251**	-.102**	.293**	.067
L	7			.027	-.129**		
	8			.078	-.058		
	9			.107*	-.174**		
	10			.232**	-.076		
	11			.056	-.011		
	12			.118**	-.137**		
	Total			.105**	-.090**		
	Means			-.024	-.222**	-.062	.506**
D	7				.582**		
	8				.565**		
	9				.542**		
	10				.503**		
	11				.158**		
	12				.528**		
	Total				.541**		
	Means				.514**	.061	.121*
B	Means					-.037	.093
W	Means						-.160**

[a]H = pH, L = cob length, D = cob diameter, B = breaking strength, W = water content at harvest, Y = yield on acre basis.

*Significant between .05 and .01.

**Significant beyond .01.

H for pH	B for breaking strength in lbs.
L for cob length in cms.	W for moisture percentage
D for cob diameter in mms.	Y for yield in bu./A.

Table 7 shows that, although many values are real values in the sense of statistical significance, none except the correlation of cob diameter and breaking strength are of appreciable magnitude. The value of the cob diameter-breaking strength r is 0.5 or larger for all locations except for District 11. Environmental influences on these variables are acting in District 11 in a different manner than in the other districts. Table 8 shows that District 11 had the highest average yield, the largest average diameter of cobs, the lowest average pH and next to the lowest average moisture percentage at harvest. Fertility level in this field was much higher than that found on the average Iowa farm. The experimental area was in a fall plowed, 5 year old alfalfa field on which a heavy manurial application of superphosphate was drilled beside the row and, at the second cultivation, a side dressing of N was added.

The significant positive mean correlation of moisture content and pH supports Standen's opinion that pH value is dependent entirely on stage of maturity; the low value of this correlation shows that there is much more involved

since less than 9 per cent of the mean moisture content variations could be attributed to the pH and vice versa. This variability is quite evident in Table 8 which gives means by districts for all characters studied.

Table 8. Character means by districts and total. 1949 data

District	No. of ears	pH	L[b] cms.	D mms.	B lbs.	W %	Y bu./A.
7[a]	462	4.86	20.41	24.13	136.48	19.24	87.16
8	501	4.90	21.46	24.51	141.81	16.42	82.62
9	422	5.01	21.94	24.41	142.83	18.46	93.56
10	448	4.88	18.96	24.03	124.96	20.04	48.17
11	473	4.78	21.25	25.21	132.33	17.63	103.99
12	1235	5.30	21.60	23.77	120.10	19.53	88.54
Mean of totals	3541	5.03	21.08	24.22	130.27	18.55	84.01

[a]See Figure 3 for field locations.

[b]L = cob length, D = cob diameter, B = breaking strength, W = water content at harvest, Y = yield.

The multiple correlation of these means was determined using yield, Y, as the dependent variable, and the standard partial regression coefficients between yield and each of the other characters were calculated and tested for significance. Two of these coefficients were insignificant, i.e. their association with yield could be accounted for

entirely through the effects of some of the other independent variates. The betas for the three significantly associated independent variates with yield and the multiple correlation coefficient of these three with yield are listed below:

$$\beta_{YL.BW} = .5468$$

$$\beta_{YB.LW} = .2196$$

$$\beta_{YW.LB} = .1344$$

$$R_{Y.LBW} = .5646$$

All of these statistics are significant beyond the 0.01 point. It should be noted that $(1-R^2)$ or approximately 68 per cent of the average variations in the yields of these hybrids for the southern half of Iowa as represented by the six test fields is still unexplained. On the other hand, considerable confidence can be taken in the portion explained because this represents relationships existing in spite of the large amount of variation among the mean yields of the 54 hybrids in the six locales.

Study of ear characters in single crosses and their inbred parents with relation to yield. 1951 crop.

It was originally planned to grow three sets of hybrids made up as all combinations of three distinct sets of inbreds for parent-progeny correlation analyses. Comparisons

were to be made among the groups as well as within the groups to test the predictive ability of such genetical statistics as would be derived. One of the sets was to be a genic sample from as large a maize population as it was feasible to get; the other two were to represent sets of hybrids being intensively selected for regional adaptability in Iowa, i.e. high yield in a particular set of environmental conditions. The primary difference between these latter groups was maturity. The abnormalities of the 1951 crop season, already noted in Table 2, caused many detrimental effects among the inbred lines through slower rates of growth and delayed maturity. It was decided that fallacious conclusions would be incurred if the original plan was followed. Therefore, these hybrid data were examined by methods similar to those used for the 1949 hybrid data. All computations for these data, both for hybrids and for inbreds, are based on individual ear records and not on plot means. The sampling variance or residual error term in all cases thus consists principally of variations between ears of identical genotype in the same hill. Genetically, this must be interpreted under the concept of genotypic-environmental interaction or variations in phenotypes resulting from varying responses of a set of specific genotypes to relatively small changes in environment. No con-

cept of these is obtained when data are analyzed on a plot or group-of-plants basis.

Simple correlations, multiple correlation and standard partial regression coefficients, β's, were calculated for all relationships of the following characters: silking date (S), cob weight (C), cob length (L), cob diameter (D), breaking strength (B) and yield or kernel weight (K). These were calculated separately for the 3 groups of single crosses and inbred parents previously described as the SNS, NC and SC groups. Table 9 shows the means for all 6 characters by groups of hybrids and parental inbreds with the number of ears used for determining these means. Table 10 shows the correlations within the hybrid groups while Table 12 shows the correlations within the groups of parental inbreds. Table 11 shows the regression coefficients and multiple correlation for all sets of material in Tables 10 and 12.

In addition, variance analyses to determine the general and specific combining ability for all characters in all groups of single crosses and to determine variation of the 6 characters among the inbreds of the various groups of parental inbreds were computed. These are presented later.

Table 9. Ear and plant character means for groups of single crosses and inbreds. 1951 crop.

Group	No. of ears	S[a] days	C gms.	L cms.	D mms.	B lbs.	K gms.
				Single crosses			
SNS	5512	11.05	34.16	20.58	22.91	81.84	185.95
NC	1751	13.56	43.55	21.48	24.91	104.53	232.16
SC	1685	17.62	47.51	22.05	24.98	125.28	231.73[b]
				Parental inbreds			
SNS	381	16.38	20.53	15.32	21.19	59.27	84.10
NC	277	20.03	21.56	15.47	22.86	59.04	81.97
SC	247	23.58	26.87	16.68	23.45	96.13	85.64

[a]S = silking date from 26 July 1951 as day 1, C = cob weight, L = cob length, D = cob diameter, B = breaking strength, K = kernel weight.

[b]The low yield in this group as compared to the NC group was undoubtedly caused by the below normal climatic conditions of 1951. These would affect a later maturing group more adversely.

Table 10. Correlation coefficients among characters of single crosses. 1951 data.

Character	Hybrid group	No. of ears	Correlation coefficients C[b]	L	D	B	K
S	SNS	5512[a]	.009[N]	-.142	.109	.108	-.016[N]
	NC	1751	-.249	-.233	-.100	-.215	-.338
	SC	1685	-.163	-.017[N]	.127	-.149	-.397
C	SNS			.440	.667	.688	.755
	NC			.669	.580	.599	.810
	SC			.452	.434	.658	.692
L	SNS				.105	-.060[N]	.607
	NC				.192	.127	.636
	SC				.164	-.057[N]	.572
D	SNS					.474	.505
	NC					.602	.535
	SC					.428	.314
B	SNS						.401
	NC						.496
	SC						.308

[a]All correlations in this table are significant beyond the 1% point unless otherwise noted; N indicated nonsignificance.

[b]See Table 9 for explanation of characters.

Table 11. Standard partial regression and multiple correlation coefficients of yield with other characters studied. 1951 data.

Group	No. of ears	Standard partial regression coefs. S^b	C	L	D	B	$R_{K.X_1}$
			Single crosses				
SNS	5512[a]	.017*	.471	.390	.131	.036	.8204
NC	1751	-.139	.506	.230	.162	----	.8402
SC	1685	-.342	.533	.296	.135	-.134	.8214
			Parental inbreds				
SNS	381	-.076	.520	.383	.098*	----	.8948
NC	277	-.501	.506	----	-.115*	-.126	.7624
SC	247	-.548	.664	----	----	-.211	.7667

[a]All betas are significant beyond $t_{.01}$ unless noted with *; these are significant between $t_{.05}$ and $t_{.01}$; missing cells in the table indicate nonsignificance with elimination of this trait from predictive regression equations which could be computed.

[b]See Table 9 for explanation of characters.

Table 12. Correlation coefficients among characters of parental inbreds. 1951 data.

Character	Inbred group	No. of ears	Correlation coefficients C[b]	L	D	B	K
S	SNS	381	-.264[a]	-.440	-.047[N]	.276	-.386
	NC	277	-.305	-.272	-.090[N]	-.033[N]	-.640
	SC	247	-.056	.293	.018[N]	-.273	-.528
	SNS			.566	.798	.347	.835
C	NC			.605	.601	.315	.550
	SC			.535	.498	.627	.563
	SNS				.193	-.290	.730
L	NC				.059[N]	-.376	.482
	SC				.062[N]	-.149*	.187
	SNS					.404	.590
D	NC					.545	.166
	SC					.399	.220
	SNS						.104*
B	NC						-.013[N]
	SC						.355

[a]All correlations in this table are significant beyond the 1% point unless otherwise noted; N indicates non-significance; * indicates significance between the 5% and 1% points.

[b]See Table 9 for explanation of characters.

Examination of Table 10 shows rather remarkable conformity of a specific association from group to group considering the known genetic diversity of the SNS group of hybrids as compared to the other two. Consequently, these significant associations, regardless of magnitude, can be interpreted as basic biological, biochemical, or physiological associations. In addition, the obviously suboptimal growth conditions for the SC group of hybrids introduces another unexpected variant into the situation and could be expected to change correlations of characters which show much response to environmental variation. Since the correlation of silking date and cob length, r_{SL}, is the only one becoming nonsignificant while the same correlation for the two other groups remains highly significant, it would seem to indicate that this is the only disturbed relationship to be expected in suboptimal situations.

Table 11 shows the standard partial regression coefficients of the characters studied with kernel weight, K, as the dependent variate. Comparing these coefficients with the correlations r_{SK}, ..., r_{BK} of Table 10 shows the independent relationships existing among the characters studied and yield. The direct relationship, for example, between breaking strength, B, and yield, K, in Table 10 is seen to vary from 0.31 to 0.50 for the different groups of hybrids. For predictive use, with values known only for B, 10 to 25

per cent of the variation in yield of hybrid ears can be accounted for. The independent relationship of B with K, seen in Table 11, is practically nonexistent. This can only mean that the direct relationship between B and K results from causes common to the phenotypic expression of B and K. Biochemically, some step or series of steps in the synthesis of materials making up kernel weight are also instrumental in the synthesis of materials contributing to breaking strength. This does not imply that the same materials are involved.

In contrast to the above, nearly all of the direct relationship between cob weight, C, and kernel weight, K, remains after elimination of the indirect but common effects of the other independent variates on C and K. The lower proportionate reduction from correlation to partial regression in this latter instance indicates a relatively greater common biochemical background between C and K than between B and K.

The consistently high values for the multiple correlation coefficient, $R_{K.X_1}$, similarly indicate the interrelationship existing between these ear characters and kernel weight, K, to be a concomitant relationship. The consistency and high values of the partial regression coefficients for C, L, and D, -- cob weight, length, and diameter, respectively, -- point to these as valuable traits

in the estimation of kernel weight. Eliminating the partial regression coefficients of silking date and breaking strength would reduce slightly the precision of kernel weight predictions based only on cob weight, length and diameter. The inconsistency and low values of the partial regression coefficients for silking date and breaking strength make them of little use in a multiple regression prediction.

One of the expensive and time consuming processes in any plant breeding program is the yield testing phase. The breeder is always aware of the inadequacy of his sampling of the myriad genotypes available. The correlation here being discussed is large enough to use in a preliminary crude separation of desirable and undesirable genotypes for yield on the basis of the three cob characters alone. The measurement of each of these traits can be easily mechanized to allow hundreds of individual cob determinations to be made in the same time and with no more effort than is used in the present laborious plot techniques. Anything which will allow sampling of more genotypes will improve efficiency.

In Table 12 are given the correlation coefficients for the same relationships as shown in Table 10. These are for the parental groups of inbreds used in the single crosses from which the data in Table 10 were derived. While the same overall picture is presented in comparing the two tables, nevertheless some apparently consistent shifts in

emphasis of specific relationships occur. The most obvious of these are the increases in inverse relationship between the silking date and kernel weight and between length and diameter among the inbreds and reduction almost to non-significance of the relationship between breaking strength and kernel weight.

From a relative gene frequency standpoint there is no difference between a group of comparisons in Table 10 and the same group in Table 12. There is, of course, a vast difference in genetic constitution with the inbred groups representing all loci in supposedly homozygous condition while the hybrid groups have some of the loci in a heterozygous condition. The correlation shifts noted may be attributed to this change in constitution. But whether these shifts are related to interallelic interactions, to interactions between loci or to a combination of both cannot be inferred.

Variance Component Analyses of Ear Characters in Hybrid and Parental Inbred Groups. 1951 Crop.

Variance component analysis has been widely used for the determination of relative effect of certain specified and measurable variates in biology. More recently the same procedure has been applied to a genetic situation of the kind investigated here i.e. the study of all the

combinants of a specified number of homozygous genotypes. In such a case the variance attributable to the differences in hybrid combinations can be subdivided into that portion coming from the common effect of the inbred parents and the portion arising out of the divergence of specific hybrid genotypes from the average of all the genotypes. The former is commonly called the general combining ability existing in a group of inbreds and the latter is known as the specific combining ability.

The amount of variation in these groups of hybrids and inbreds is seen in Tables 13 through 16. Mean square values are tabulated by groups for the 6 characters studied. A comparison of the variation associated with the parental inbred lines, - "among inbred parents," - in Tables 13 through 15 shows the relative diversity of the SNS material in contrast to the greater uniformity in the NC and SC groups. While these items show the comparative uniformity or diversity of progeny groups, Table 16 shows a similar comparison for the behavior of the inbreds themselves. In these comparisons, only the mean square associated with breaking strength in the SC inbreds is larger than the corresponding mean square in the SNS inbreds. For all other comparisons the largest values are found in the SNS group.

Table 13. Mean squares for all characters of SNS hybrids. 1951 data.

Source of variation	df	Mean squares					
		S[a]	C	L	D	B	K
Total	5511	17.12	76.59	4.34	6.55	1,127.17	1,558.65
Among reps.	9	1014.99[b]	1,258.07	69.75	26.17	6,649.05	15,111.39
Among inbred parents	14	2488.63	12,471.61	397.80	1533.08	241,582.73	216,642.30
Among hybrids	90	77.36	161.93	32.73	33.33	9,460.15	7,331.18
Among ears (Error)	5398	8.04	41.05	2.74	2.11	35540	881.98

[a]S = silking date (days from 26 July 1951), C = cob length, D = cob diameter, B = breaking strength, K = kernel weight.

[b]All mean squares are significant beyond the .01 point.

Table 14. Mean squares for all characters of North Central (NC) hybrids. 1951 data.

Source of variation	df	Mean squares					
		S[a]	C	L	D	B	K
Total	1750	11.60	68.95	3.74	3.31	1,028.12	1,557.69
Among reps.	9	369.42[b]	358.28	13.71	3.89	3,960.19	8,623.54
Among inbred parents	11	287.93	1227.41	142.59	198.37	21,060.78	24,577.61
Among hybrids	54	40.35	422.71	20.53	5.66	7,784.46	7,148.12
Among ears (Error)	1676	6.94	48.39	2.23	1.95	663.21	1,188.54

[a]See Table 13 for explanation of characters.

[b]All mean squares are significant beyond the .01 point.

Table 15. Mean squares for all characters of South Central (SC) hybrids. 1951 data.

Source of variation	df	Mean squares					
		S[a]	C	L	D	B	K
Total	1684	14.57	118.80	5.76	4.64	1,845.55	2,045.80
Among reps.	9	890.41[b]	598.39	39.58	20.17	3,622.39	20,059.36
Among inbred parents	11	200.11[N]	4501.61	315.96	272.57	125,380.88	33,575.43
Among hybrids	53	159.48	703.62	24.28	26.65	12,996.43	10,681.67
Among ears (Error)	1611	3.64	66.96	2.85	1.67	625.27	1,445.77

[a]See Table 13 for explanation of characters.

[b]All means squares are significant beyond the .01 point unless otherwise noted; N indicates nonsignificance.

Table 16. Mean squares for all characters of all groups of inbreds. 1951 data.

Source of variation	df	Mean squares					
		S[a]	C	L	D	B	K
		SNS Inbreds					
Total	380	33.76[b]	84.89	7.86	10.52	1,387.28	1,285.13
Among reps.	9	122.93	91.25	7.29	5.15	472.11[N]	1,247.73
Among inbreds	14	678.66	2156.97	161.13	232.62	21,937.22	26,607.55
Among ears (Error)	357	6.22	3.47	1.87	1.94	604.75	293.04
		NC Inbreds					
Total	276	15.49	19.53	4.64	4.85	1,394.26	517.40
Among reps.	9	47.56	21.14[N]	4.06[N]	3.98[N]	1,077.56[N]	665.53[*]
Among inbreds	11	185.84	193.16	58.10	68.44	18,672.87	483.88[N]
Among ears (Error)	256	7.05	12.01	2.37	2.15	662.95	326.51
		SC Inbreds					
Total	246	22.90	79.50	8.77	5.71	3,097.39	676.74
Among reps.	9	34.51	24.17[N]	3.04[N]	3.60[N]	800.97[N]	544.54[N]
Among inbreds	11	362.49	1331.90	145.95	77.14	49,682.18	7,760.50
Among ears (Error)	226	5.91	20.74	2.32	2.32	921.44	337.22

[a]See Table 13 for explanation of characters.

[b]All mean squares are significant beyond the .01 point unless otherwise noted; * indicates significance between .05 and .01; N indicates nonsignificance.

The uniformity of the inbreds used in the NC hybrids is clearly indicated by the small mean square values among inbreds for all characters. That this uniformity also extends to the single cross performance of these inbreds can be inferred from the relatively low values in Table 14 as compared to Tables 13 and 15.

Further confirmation of these inferences comes from investigating the variance components associated with the various assumedly independent sources of deviation which have been measured. These components are derived from the mean squares and are additive variances having coefficients depending on the number of items aggregated for the estimate of the specific component. Because of the variation in numbers of items in the subdivisions of the present study, adjusted values of these coefficients were calculated. It was suggested that these adjusted values should be harmonic mean values of the various subgroup frequencies. These were calculated for all components derived and are presented in Tables 17 and 18 for use with the hybrid and inbred groups, respectively. Differences between these harmonic mean values and the corresponding arithmetic means are negligible in these studies but the adjustments were made in the interests of statistical precision.

Table 17. Coefficients of variance components in expected mean squares for hybrid groups. 1951 data. (Harmonic means of frequencies of subgroups.)

Hybrid group	Coefficients		
	k_H[a]	k_P	k_R
SNS	49.9520	725.7102	550.0450
NC	26.2627	291.4246	173.9299
SC	25.6517	280.2260	167.1131

[a] k_H = coef. for hybrid combns. (specific combining ability;
k_P = coef. for inbred parents (general combining ability;
k_R = coef. for replicates.

Table 18. Coefficients of variance components in expected mean squares for inbred groups. 1951 data. (Harmonic means of frequencies of subgroups.)

Inbred group	Coefficients	
	k_I[a]	k_R
SNS	24.9498	37.6786
NC	22.2273	27.4482
SC	17.2513	24.2724

[a] k_I = coef. for among inbreds component;
k_R = coef. for among replicates.

The variance components are presented in two forms. In Table 19 are the computed values for the sources of variation in the hybrid groups and in Table 20 the same values have been recomputed as the proportionate parts of a total variance complex adding up to 1.00.

The component V_P is that component in the variance among hybrid genotypes arising from differences in the single cross progeny performance which is associated with particular inbred parents. This is the component usually spoken of and used as a measure of the general combining ability.

The component V_H is a similar fraction of the total variance which includes the variation arising from differences among specific genotypic combinations and is usually called specific combining ability.

The other two portions shown in these tables, V_R and V_E, come from variations among replicates and among ears, respectively. The portion V_E is used as the error term since it consists of the random variation in the tests whose average value is assumed to be zero.

In the variance component tables presented here the primary grouping is by character studied and within each of these groups are given the components for the different sets of hybrids. The first thing to be noted in Table 19 is the large size of the V_E components, regardless of char-

Table 19. Calculated values of variance components for all characters of all hybrid groups. 1951 data.

Hybrid group	Variance components			
	V_R[a]	V_P	V_H	V_E
		Silking date		
SNS	1.831	3.323	1.388	8.040
NC	2.084	0.850	1.272	6.937
SC	5.306	0.145	6.045	3.640
		Cob weight		
SNS	2.213	16.962	2.420	41.055
NC	1.782	2.761	14.253	48.392
SC	3.180	13.553	24.820	66.955
		Cob length		
SNS	0.122	0.503	0.600	2.741
NC	0.066	0.419	0.697	2.234
SC	0.220	1.041	0.835	2.848
		Cob diameter		
SNS	0.044	2.067	0.625	2.111
NC	0.011	0.661	0.141	1.946
SC	0.111	0.842	1.364	1.669
		Breaking strength		
SNS	11.442	319.856	182.270	355.396
NC	18.956	45.556	271.155	663.207
SC	17.935	401.049	482.275	625.271
		Kernel weight		
SNS	25.870	288.422	129.108	881.980
NC	42.747	59.808	226.922	1188.541
SC	111.383	81.697	360.050	1445.770

[a] V_R = variance component of replicates, V_P = component of inbred parents, V_H = component of hybrid combinations, V_E = component of individual ears used as error. V_P and V_H are components for general and specific combining abilities, respectively.

Table 20. Proportionate values of variance components for all characters of all groups of hybrids. 1951 data.

Hybrid group	Proportionate component values			
	V_R[a]	V_P	V_H	V_E
		Silking date		
SNS	.1256	.2279	.0952	.5513
NC	.1870	.0763	.1142	.6225
SC	.3499	.0096	.4005	.2400
		Cob weight		
SNS	.0353	.2708	.0386	.6553
NC	.0265	.0411	.2121	.7203
SC	.0293	.1249	.2287	.6171
		Cob length		
SNS	.0307	.1268	.1514	.6911
NC	.0193	.1227	.2040	.6540
SC	.0445	.2106	.1689	.5760
		Cob diameter		
SNS	.0090	.4265	.1290	.4355
NC	.0040	.2396	.0511	.7053
SC	.0278	.2112	.3422	.4188
		Breaking strength		
SNS	.0132	.3681	.2098	.4090
NC	.0190	.0456	.2715	.6639
SC	.0117	.2627	.3159	.4097
		Kernel weight		
SNS	.0195	.2176	.0974	.6655
NC	.0282	.0394	.1495	.7829
SC	.0557	.0409	.1801	.7233

[a] V_R = variance component of replicates, V_P = component of inbred parents, V_H = component of hybrid combinations, V_E = component of individual ears used as error. V_P and V_H are components for general and specific combining abilities, respectively.

acter or hybrid group, when compared to the two which are of genetic interest, V_P and V_H. This single relationship is more clearly seen in Table 20 which shows the proportionate parts of these components in the whole picture of variation.

The second point to be observed among the calculated component values is the difference in degree of heterogeneity shown for a particular character among the hybrid groups. As an example, in the V_H entries for the cob weight, C, much greater variation exists among specific hybrid combinations in the South Central group of hybrids than among the specific combinations of the SNS group as shown in the relative values of these two entries. Selection for cob weight will be more effective in the SC group than in the SNS group.

Another point of interest, also to be seen in the table of proportionate values, is the relative importance of the two components V_P and V_H. In most instances for the characters in the SNS hybrids, the V_P component is larger than the V_H component. In the NC and SC groups the reverse relation holds. In the former situation, more variation is contributed because of differences in progeny performance potential of the inbred parents while in the latter case the variation is contributed by differences between specific combinations. In one sense the higher values of V_P reflect

dominance effects while higher values of V_H reflect interactions within specific genotypes.

One other point should be noted here. The intensive selection practiced among inbred combinations for uniform maturity and high yield show clearly in the general combining ability component, V_p, for the two characters silking date and kernel weight in the NC and SC groups. These values are lower in contrast to the V_H components than for any of the other characters. The indications are that among the parental inbreds of these groups practically no genetic differences in potential for maturity and yield remain.

Table 21 shows the similar component analysis for the inbred groups. The left side of the table shows the calculated mean square values, and the right side of the table shows the values recomputed on a proportionate parts basis. Here V_I represents the variance portion attributable to differences among inbred means, V_R is the portion attributable to replicates, and V_E is the portion contributed by the pooled random variations among ears. This last component is used for the error term. In general, the most apparent contrast of these values with those for the hybrids is in the portion of error. Except for the kernel weight error component in the NC inbreds, these are lower values than found among the hybrid groups of V_E components. The

Table 21. Calculated values and proportionate parts of variance components for all characters of all groups of inbreds. 1951 data.

Inbred group	Variance components: Calculated values V_R	V_I	V_E	Proportionate parts: V_R[a]	V_I	V_E
			Silking date			
SNS	3.097	26.952	6.220	.0854	.7431	.1715
NC	1.476	8.044	7.045	.0891	.4856	.4353
SC	1.178	20.670	5.913	.0424	.7446	.2130
			Cob weight			
SNS	2.330	86.513	3.474	.0253	.9370	.0377
NC	0.332	8.150	12.013	.0162	.3977	.5861
SC	0.141	97.600	20.741	.0012	.8238	.1750
			Cob length			
SNS	0.144	6.383	1.865	.0172	.7606	.2222
NC	0.062	2.508	2.365	.0126	.5082	.4792
SC	0.030	8.326	2.321	.0028	.7798	.2174
			Cob diameter			
SNS	0.085	9.245	1.942	.0075	.8202	.1723
NC	0.066	2.982	2.152	.0127	.5735	.4138
SC	0.053	4.337	2.319	.0079	.6464	.3457
			Breaking strength			
SNS	0.000	855.016	604.748	.0000	.5857	.4143
NC	15.105	810.261	662.953	.0101	.5444	.4455
SC	0.000	2826.497	921.439	.0000	.7541	.2459
			Kernel weight			
SNS	25.338	1054.698	293.037	.0185	.7681	.2134
NC	12.351	7.080	326.510	.0357	.0205	.9438
SC	8.542	430.303	337.216	.0110	.5545	.4345

[a] V_R = variance component for replicates; V_I = component for inbreds; V_E = variance for ear used as error.

lower values for V_I in the NC group as compared to the other inbred groups again points out the uniformity of performance of this group of inbreds. From one standpoint this is very remarkable. The inbreds in this group have originated in 5 different Corn Belt states. Most of them are relatively old established strains as can be seen by referring to their pedigrees listed in Table 31 in the supplement. Remembering their relative uniformity of performance in hybrid combinations, both from the standpoints of general and of specific combining abilities, hints at the idea that the traits necessary for yield in this maturity group are all present in these inbreds as far as the Corn Belt maize genic reservoir is concerned. To anyone familiar with these inbreds, the relationship between plant or ear phenotype in the inbred and yield potential in hybrid combination must appear slight because many distinguishing phenotypic characteristics are present among this group of inbreds.

One item of contrast should be noted in these analyses. The breaking strength error variance component in the inbred groups shown in Table 21 indicates that the SNS and NC lots are more uniform in their reactions to environmental variations than in the SC lot. The genic groups of the SNS and SC lots show the expected error variance reductions in the heterozygous condition of the single crosses, but the NC

hybrids show no comparable reduction in error variance. This proportionate error variance increase of the NC hybrid group may be contributed by a relatively greater amount of genetic-environmental interaction in the heterozygous genotypes as compared to the homozygous genotypes of the parental inbred group. It can be inferred that this group of hybrids is more responsive to environmental variations and would exhibit a greater range of adaptability than the parental inbreds from which they are derived.

From the additive variance model assumed, the V_H, specific combining ability, component contains most of the dominance and epistatic effects in addition to part of the genetic-environmental interactions. Probably most of the genetic-environmental interactions are left to be included with the environmental variation in the error variance component of the hybrid.

Midcob Color Relationships to Other Ear Characteristics

The subjective nature of this study would not permit the inclusion of the data in the foregoing statistical studies performed on the other characters. Pertinent associations of these midcob color series with other traits

are presented here in tabular form. In spite of the subjective manner in which it has been handled, midcob color is certainly one of the important and easily used traits in the yield complex.

It was mentioned earlier in this report that if the traits of acidity, breaking strength and midcob color were associated with yield producing factors, then selection for yield alone, as has been done in maize breeding, would automatically increase the incidence of the unnoticed traits. Although not specifically shown in this report, such trends have been noted for pH and breaking strength. The trend in midcob color shift can be seen indirectly by comparing the relative occurrence of noncolored and colored strains shown in Table 5 which contains data on inbreds grown in 1932 with the relative frequencies of colored and noncolored types seen in the data on midcob color presented here for the 1949 and 1951 crops (see Tables 22 and 24). It is quite obvious that the gene frequency for midcob color genes has shifted, even allowing for dominance of midcob color and comparison of inbreds in 1932 with single crosses at present.

Table 22. Midcob color relationships with
Arranged by location and color

District No.	Red color series grades: No color No. of ears	No color Means	Pink No. of ears	Pink Means	Red No. of ears	Red Means	Distr No. o ears
							:pH
7[a]	94	4.94	215	4.84	153	4.83	462
8	90	4.97	317	4.87	94	4.95	501
9	87	5.18	193	4.97	142	4.95	422
10	123	4.95	189	4.87	136	4.84	448
11	85	4.94	196	4.77	192	4.72	473
12	261	5.48	569	5.28	405	5.22	1235
Totals	740	5.16	1679	5.00	1122	4.98	3541
							Cob length in c
7	94	21.49	215	20.46	153	19.67	462
8	90	23.03	317	21.37	94	20.23	501
9	87	24.13	193	21.70	142	20.92	422
10	123	20.11	189	18.68	136	18.31	448
11	85	22.32	196	21.00	192	21.04	473
12	261	23.45	569	21.65	405	20.33	1235
Totals	740	22.54	1679	21.04	1122	20.18	3541

[a]See Figure 3 for location of these districts in Iowa.

.or relationships with ear characters of single crosses.
by location and color grade. 1949 data.

Red of 's	Means	District totals No. of ears	Means	Brown color series grades No color No. of ears	Means	Tan No. of ears	Means	Brown No. of ears	Means
		pH							
3	4.83	462	4.86	17	4.85	339	4.86	106	4.84
4	4.95	501	4.90	5	4.80	415	4.89	81	4.96
2	4.95	422	5.01	1	4.59	256	5.01	165	5.00
6	4.84	448	4.88	29	4.90	271	4.89	148	4.85
2	4.72	473	4.78	11	4.89	280	4.80	182	4.75
5	5.22	1235	5.30	9	5.23	764	5.31	462	5.30
2	4.98	3541	5.03	72	4.92	2325	5.03	1144	5.04
		Cob length in cms.							
3	19.67	462	20.41	17	21.24	339	20.51	106	19.96
4	20.23	501	21.46	5	22.80	415	21.62	81	20.52
2	20.92	422	21.94	1	23.00	256	22.21	165	21.50
6	18.31	448	18.96	29	20.48	271	18.99	148	18.62
2	21.04	473	21.25	11	23.36	280	21.28	182	21.08
5	20.33	1235	21.60	9	23.33	764	22.11	462	20.74
22	20.18	3541	21.08	72	21.65	2325	21.34	1144	20.51

a.

Table 22 (continued)

District No.	Red color series grades: No color No. of ears	No color Means	Pink No. of ears	Pink Means	Red No. of ears	Red Means	District totals No. of ears	District totals Means
						Cob diameter in mms.		
7	94	23.79	215	24.30	153	24.10	462	24.13
8	90	24.23	317	24.61	94	24.45	501	24.51
9	87	24.16	193	24.26	142	24.76	422	24.41
10	123	23.91	189	24.13	136	24.00	448	24.03
11	85	24.44	196	25.11	192	25.67	473	25.21
12	261	23.17	569	23.82	405	24.06	1235	23.77
Totals	740	23.76	1679	24.27	1122	24.46	3541	24.22
						Breaking strength in lbs.		
7	94	125.14	215	132.70	153	148.73	462	136.48
8	90	126.41	317	141.10	94	159.04	501	141.81
9	87	124.84	193	138.99	142	159.06	422	142.83
10	123	106.53	189	123.98	136	142.99	448	124.96
11	85	116.60	196	125.36	192	146.40	473	132.33
12	261	93.75	569	117.08	405	141.27	1235	120.10
Totals	740	110.09	1679	127.87	1122	147.12	3541	130.27

Table 22 (continued)

Red		District totals		Brown color series grades					
				No color		Tan		Brown	
. of ars	Means	No. of ears	Means	No. of ears	Means	No. of ears	Means	No. of ears	Means
		Cob diameter in mms.							
53		462		17		339		106	
	24.10		24.13		24.18		24.23		23.80
94		501		5		451		81	
	24.45		24.51		26.00		24.52		24.40
42		422		1		256		165	
	24.76		24.41		21.00		24.26		24.66
136		448		29		271		148	
	24.00		24.03		24.66		24.17		23.65
192		473		11		280		182	
	25.67		25.21		24.46		25.03		25.54
405		1235		9		764		462	
	24.06		23.77		24.67		23.71		23.85
122		3541		72		2325		1144	
	24.46		24.22		24.56		24.20		24.24
		Breaking strength in lbs.							
153		462		17		339		106	
	148.73		136.48		106.59		138.60		134.45
94		501		5		415		81	
	159.04		141.81		98.00		141.82		144.41
142		422		1		256		165	
	159.06		142.83		84.00		138.45		149.91
136		448		29		271		148	
	142.99		124.96		87.62		127.47		127.61
192		473		11		280		182	
	146.40		132.33		102.45		128.86		139.41
405		1235		9		764		462	
	141.27		120.10		76.67		114.43		130.31
122		3541		72		2325		1144	
	147.12		130.27		93.67		128.74		135.6

In Table 22 are presented the mean values of measured characters for the various 1949 districts as they were calculated for the color grades of the two color series. District means are given in the center columns of the table for reference to the various subgroups. The mean variations from district to district can be seen as well as the variations among the various midcob color grades. Comparison of these data distributions with Figure 3 (p. 50) shows some evidence of geographical stratification.

To be noted in the pH relationship is the inverse variation of pH with increase of color in the red series while a direct variation of pH with color intensity occurs in the brown series as an overall characteristic of the variation. Within the individual districts the red color follows the overall pattern very well but the brown color relationship shows considerable variation. The only reasonable explanation for the red relationship would be that of maturity differences between ears. The development of both these traits as a direct function of maturity could explain the gradient seen here.

Among the district means the apparently higher pH for the eastern part of this area (Fields 9 and 12) is unexplainable. Soil types differ in these locations and nothing is known of the 1949 climatic variation which might give some clue to this change from the other four districts.

Cob length shows a similar inverse gradient in the red color series both by districts and in the totals. The magnitude of the difference between colorless and pink groups again could be a function of maturity since longer ears are probably later than shorter ears of the same genotypes. The lower inverse gradient in the brown series may be related to a similar maturity gradient.

Among the district means the most striking deviant is District 10. This district in the southwestern corner of Iowa is in the driest part of the state and the experimental area was in a gravelly soil. These two environmental characteristics could easily account for the short ears found here. Again Districts 9 and 12 show the highest values although no distinctive difference exists between this area and the rest of the test location areas.

Only small differences exist among the cob diameter means, although, with the numbers of ears involved, some of the larger differences might be statistically significant. It would seem that these two characteristics were biologically independent.

Breaking strength variations show the greatest percentage changes of any of these traits in relation to mid-cob color grades. Distinct and steep positive gradients occur in both the red and brown color series. Decided environmental effects are seen in the pattern of variation

among district means. Nevertheless, the range of mean variations among districts is not as great as that shown in either of the color series. The minimal mean value in the colorless grade of the brown series may be an artefact considering the relatively small number of individuals contributing to this mean.

To see more clearly some of the aspects entering into this complexity of relationship, the pertinent subgroup means have been presented in a different arrangement in Table 23. This table has a geographical conformation (see Figure 3) which shows the latitudinal variation among the six districts. An unusually consistent difference in breaking strength between the northern and southern tiers of districts can be seen in the series of means subgrouped into the red midcob series. These differences are consistent even in the comparison of pairs of subgroup means. A positive gradient between north and south subgroup means exists in going from west to east (left to right in this portion of the table).

A similar latitudinal difference shows in the brown series of breaking strength means, but no longitudinal gradient is evident. The range deviations from the district means are not as great in this series nor would the variance be as large here as in the red series.

Table 23. Mean variations in breaking strength associated with district location and midcob color. 1949 data.

Red midcob series				Brown midcob series			
District no.	7	8	9	District no.	7	8	9
No color	125.15[a]	126.41	124.84	No color	106.59	98.00	84.00
Pink	132.70	141.10	138.99	Tan	138.60	141.82	138.45
Red	148.73	159.04	159.07	Brown	134.49	144.48	149.98
District no.	10	11	12	District no.	10	11	12
No color	106.53	116.60	93.75	No color	87.62	102.45	76.67
Pink	123.98	125.36	117.08	Tan	127.47	128.86	114.43
Red	142.99	146.40	141.27	Brown	127.68	139.46	130.38

[a]Mean breaking strength in lbs. for the various midcob color classes by geographical location. All data based on the same set of hybrids in each location. See Figure 3 for location of districts in Iowa.

The latitudinal differences cannot be explained in the light of any known or conceivable variations expected to be associated with latitude. Only on the premise that, since the preliminary breeding and testing work is done in the District 8 area, adaptive selection operates among the strains to limit the adaptation response latitudinally can the higher values be anticipated for the northern tier of districts.

These were the only characters which could be compared on an individual ear basis with midcob color grades in this material. In the 1951 data where all characters were studied on an individual ear basis further comparisons can be made.

Table 24 presents the midcob color relationships with all the characters examined in 1951 for the three groups of single crosses. The table is subdivided vertically in the same manner as Table 22 and horizontally to show direct relationships of a specific character and the two series of midcob color grades. The first section presents the information on silking dates.

The differences in maturity between the three groups of hybrids are plainly seen. A consistent negative gradient of silking date with presence and intensity of midcob color is seen in the red color series in spite of the differences in gene frequency for midcob color and maturity among the hybrid groups. Since red midcob color expression is dependent on stage of maturity, some inverse relationship of these

Table 24. Midcob color relationship
Means of various characters by midcob color cla

Hybrid group	Red color series grades: No color No. of ears	Means	Pink No. of ears	Means	Red No. of ears	Means	Group mea No. of ears
							Silking dates in days from 26
SNS	2201		2126		916		5243
		11.58		10.72		9.92	
NC	395		1067		289		1751
		13.85		13.71		12.62	
SC	494		993		198		1685
		18.77		17.49		15.39	
Totals	3090		4186		1403		8679
		13.02		13.09		11.23	
							Cob weights in gms.
SNS	2201		2126		916		5243
		33.74		34.30		34.66	
NC	395		1067		289		1751
		42.41		44.16		42.83	
SC	494		993		198		1685
		42.67		49.12		51.52	
Totals	3090		4186		1403		8679
		36.27		40.33		38.73	
							Cob lengths in cms.
SNS	2201		2126		916		5243
		20.98		20.39		20.45	
NC	395		1067		289		1751
		21.16		21.54		21.65	
SC	494		993		198		1685
		22.46		22.04		21.12	
Totals	3090		4186		1403		8679
		21.24		21.07		20.79	

4. Midcob color relationships. 1951 hybrids.
haracters by midcob color classes in red and brown series.

Red	Group means		Brown color series grades					
			No color		Tan		Brown	
of rs Means	No. of ears	Means	No. of ears	Means	No. of ears	Means	No. of ears	Means
Silking dates in days from 26 July 1951								
16	5243		326		3215		1702	
9.92		10.94		10.44		10.93		11.07
39	1751		12		1212		527	
12.62		13.56		10.75		13.46		13.87
98	1685		11		1290		384	
15.39		17.62		16.64		17.84		16.90
03	8679		349		5717		2613	
11.23		12.77		10.64		13.02		12.48
Cob weights in gms.								
16	5243		326		3215		1702	
34.66		34.13		31.89		34.05		34.70
89	1751		12		1212		527	
42.83		43.55		44.67		44.20		42.02
98	1685		11		1290		384	
51.52		47.51		38.46		47.19		48.84
03	8679		349		5717		2613	
38.73		38.63		32.54		39.17		38.25
Cob lengths in cms.								
16	5243		326		3215		1702	
20.45		20.65		21.29		20.68		20.46
89	1751		12		1212		527	
21.65		21.48		22.25		21.52		21.34
98	1685		11		1290		384	
21.12		22.05		22.00		22.14		21.78
03	8679		349		5717		2613	
20.79		21.09		21.34		21.19		20.83

Table 24 (continued)

Hybrid group	Red color series grades: No color No. of ears	No color Means	Pink No. of ears	Pink Means	Red No. of ears	Red Means	Group means No. of ears	Group means Means
							Cob diameters in mms.	
SNS	2201	23.24	2126	22.68	916	22.58	5243	22.90
NC	395	24.87	1067	25.03	289	24.52	1751	24.91
SC	494	24.74	993	25.20	198	24.46	1685	24.98
Totals	3090	23.68	4186	23.88	1403	23.24	8679	23.71
							Breaking strengths in lbs.	
SNS	2201	73.48	2126	85.12	916	85.61	5243	80.32
NC	395	104.13	1067	104.77	289	104.21	1751	104.53
SC	494	101.35	993	131.30	198	154.79	1685	125.28
Totals	3090	81.86	4186	101.08	1403	99.21	8679	93.93
							Kernel weights in gms.	
SNS	2201	186.75	2126	186.57	916	186.56	5243	186.64
NC	395	219.02	1067	235.82	289	236.51	1751	232.16
SC	494	207.02	993	241.66	198	243.38	1685	231.73
Totals	3090	194.24	4186	212.19	1403	204.89	8679	204.62

Table 24 (continued)

Red of 's	Group means: No. of ears	Group means: Means	Brown color series grades: No color: No. of ears	No color: Means	Tan: No. of ears	Tan: Means	Brown: No. of ears	Brown: Means
Cob diameters in mms.								
16	5243		326		3215		1702	
		22.90		23.43		22.70		23.15
39	1751		12		1212		527	
		24.91		25.25		25.05		24.58
38	1685		11		1290		384	
		24.98		24.64		25.01		24.89
03	8679		349		5717		2613	
		23.71		23.53		23.72		23.70
Breaking strengths in lbs.								
16	5243		326		3215		1702	
		80.32		57.81		81.12		83.12
39	1751		12		1212		527	
		104.53		93.67		106.46		100.36
38	1685		11		1290		384	
		125.28		86.54		123.60		132.06
03	8679		349		5717		2613	
		93.93		59.95		96.08		93.79
Kernel weights in gms.								
16	5243		326		3215		1702	
		186.64		188.86		186.65		186.21
89	1751		12		1212		527	
		232.16		227.33		235.14		225.40
38	1685		11		1290		384	
		231.73		212.00		231.73		232.32
03	8679		349		5717		2613	
		204.62		190.91		207.01		201.01

traits is expected. Whether or not the amount appearing here can be completely explained by such expectancy is doubtful in view of the subnormal season's influences on maturity. No relationship of the brown color series with silking date is apparent upon observation of that section of the table.

None of the variations and interactions of midcob colors seen in their relationships with cob weights, cob lengths, or cob diameters need special explanation. The expected effects of maturity on these three traits can account for considerably more variation than is shown.

The concordance in overall averages for breaking strength and kernel weight in both series of midcob colors is evidence for an interrelationship of these three characters. However, the correlation and partial regression studies of breaking strength and kernel weight indicated their independence of each other. The relationship seen here must be an indirect one caused by the same biochemical reactions that develop the expression of midcob color. A further point here is the evidence in both series for the optimal color level to be at the lesser intensity of color expression. Since nothing is known of the chemical interactions involved, it is probably useless to speculate on reasons for this. Nevertheless, in the interests of probing the unknown, a discussion of these phenomena will be indulged in later.

In an attempt to evaluate midcob color effects per se regardless of hue, the data from which Table 24 was prepared were regrouped on a color intensity basis alone. This constitutes removing from the colorless group of the red series data from those cobs having the solitary expression of tan or brown and from the colorless group of the brown series data for those cobs showing solitarily pink or red. The two rare groups, pink with brown and red with tan, would both be included in the "intense color" group. Table 25 shows the means of all characters for all 1951 hybrid groups computed on this classification base as well as for all 1951 hybrid data in a composite group. Although no striking changes in relationships occur by this regrouping, there does emerge a parallel performance through the intensity range of the four characters: silking date, cob weight, breaking strength, and kernel weight. The correlation studies presented earlier in this report may account for some of this, but the usual negative correlation of maturity and yield seems to be completely reversed when midcob color is considered as an additional variate. At least, this can be considered as additional evidence for the interrelationship of this group of characters.

Table 25. Intensity of midcob pigmentation in relation to various characters. 1951 data.

Color intensity	No. of ears	Means of characters: S[a] days	C gms.	L cms.	D mms.	B lbs.	K gms.
		SNS hybrids					
No color	322	10.50	31.87	21.30	23.44	57.64	188.98
Intermediate	3195	10.93	34.02	20.68	22.71	80.97	186.53
Intense color	1726	11.05	34.75	20.47	23.14	83.36	186.42
		North Central hybrids					
No color	12	10.75	44.67	22.25	25.25	93.67	227.33
Intermediate	1207	13.47	44.21	21.53	25.06	106.37	235.16
Intense color	532	13.80	42.03	21.35	24.57	100.61	225.45
		South Central hybrids					
No color	9	16.56	35.67	21.33	24.56	78.78	198.89
Intermediate	1279	17.86	47.16	22.16	25.01	123.15	231.81
Intense color	397	16.89	48.91	21.73	24.89	133.21	232.22
		All 1951 hybrids					
No color	343	10.67	32.42	21.33	23.53	49.45	190.59
Intermediate	5681	13.03	39.14	21.19	23.72	95.86	207.06
Intense color	2655	12.48	38.32	20.83	23.69	94.27	201.21

[a]S = silking date (days from 26 July 1951), C = cob weight, L = cob length, D = cob diameter, B = breaking strength, K = kernel weight.

A comparison can be made between the SC group in Table 24 and the District 8 group of Table 22 of those characters appearing in both tables. As mentioned previously, 54 of the hybrids in the SC group made up the District 8 hybrids, and the remaining SC hybrids involve all the parental inbreds of District 8. This comes from the fact that the twelve parental inbreds of the SC group are comprised of the eleven parental inbreds of the 1949 hybrids plus one additional inbred. The slightly higher group averages for cob length and diameter in the 1951 material probably reflect a closer to optimal growth environment in 1951 and the lower value for the 1951 breaking strength mean probably reflects the relative immaturity of the strains in the latter year. This is an interesting comparison because climatologically the two seasons are close to records for the extremes in Iowa. These may well be unique data in representing the limits of the phenological range of these maize genotypes in this area.

DISCUSSION

The results presented here are indicative of some of the interrelationships existing in maize which contribute to the genetic and biochemical complex measured at the end of a crop season as yield. No one element in the group studied here was found to be wholly dependent on some one other element in the group. Nor was any single character found to be uninfluenced by environment.

These data show that pH of maize cob meal extracts is associated with Nigrospora resistance and with midcob color. That pH is simply a reflection of stage of maturity as stated by Standen is belied by the data of 1932 and 1949. Both those years were exceptional in allowing maize to complete its expected maturity before a killing frost occurred. Table 5 shows the variation in pH among inbred means in the 1932 season and Table 26 shows the similar situation of pH variation among single cross means. In the latter case particularly, where selection for uniform maturity within the entire group of hybrids was practiced, distinctive variations in pH are seen between hybrids as well as between fields. These are to be interpreted as arising from genotypic diversity and from variation in the reactions of specific genotypes to varying environments and not to

variations in stage of maturity.

On the other hand Standen, as well as the observers before him, was correct in associating the stage of maturity with Nigrospora incidence. And in as far as the stage of maturity affects the expression of the genetic potential for pH in a strain, correlation of pH with maturity will be found. This is mentioned because of the inevitable balance of conflicting interactions which must be achieved for maximum yield. Later strains yield more than earlier strains but when these later strains have their growth arrested before maturation by an early frost or a continuing early fall drouth or an entirely slow season like 1951, then a stage of physiological susceptibility to disease occurs which has little or no connection with the genetic potential for disease resistance present in a strain.

These are precisely the horns of the dilemma which threaten maize breeders in the United States now.

These data also show that selection for yield by currently accepted experimental procedures will automatically cumulate whatever genetic background is responsible for the development of high levels of breaking strength in maize cobs. This also cumulates the factors for heavier weight of cobs as was shown in the 1951 data presented. As a criterion of selection for inclusion in a breeding program, it may well be that cob weight data could be more useful and practicable.

Midcob color also cumulates in the breeding nursery population automatically, although the data presented show that the intermediate or less intense degree of color may be more preferable from a yield index standpoint than more intense shades of color. This preference in yield is more noticeable in the brown color series cataloged here than in the red series.

Knowing that pH, midcob color, cob weight, and breaking strength are developing concurrently with the final maturation stages of the kernel, that interrelationships of these characters with yield exist, and that pH of the mature maize cob is associated with resistance to Nigrospora raises the question of the possible existence of some one chemical or physico-chemical complex which could account for the basic interrelationship of these apparently divergent biochemical processes.

It was noted that Wagner (33) had found silicon as an essential element for plant growth in an extensive and meticulous study involving a number of different species. In the course of Wagner's study it was observed that plants growing at suboptimal Si ion concentrations in the greenhouse were more susceptible to mildew infections. In addition, infections spread at a more rapid rate over the plants at suboptimal levels. These observations were made with the powdery mildew fungus, Erysiphe graminis (sic!) as the causal

organism and with different species of plants involved.

Because of the ease of culture and the size of the leaf blades, cucumber was used for detailed studies of Si ion physiology in the plants. Observations were made on the relative rates of spread of the mildew organism on leaves of various plants growing at minimal to luxuriant levels of Si ion. Both the rate of mycelial spread and the rate of fungal sporulation was found to vary inversely with the Si ion level in the nutrient culture solutions. It was further found that plants growing at the high levels of available Si had greatly increased resistance to mildew.

Leaf tissue discs cut from leaves at high and low levels of Si nutrition were suspended in a warm dry atmosphere. Successive weighings showed markedly less moisture loss from the high Si leaf discs as compared to low Si discs. To prove the presence of varying amounts of Si in the tissue, and at the same time, find its approximate location in leaves, more discs were cut, placed on glass slides and ashed in a muffle furnace. The ash fragments were washed with concentrated HCl and it was found that a silica skeleton occurred in the epidermal cells which retained the form and shape of the tissue structure. Ordinarily, silica is found only in the gland hairs and basal cells of cucumber. Wagner feels that the additional silica content impedes the penetration of the fungus although not stopping it completely.

Noll (13) has found a similar situation in connection with studies on the yellow leaf rust infection of wheat, Triticum aestivum, which is caused by Puccinia glumarum. Instead of ashing his leaf samples, Noll cleared the green leaf tissue with acids and studied the location of silica crystals in the leaf under the microscope. He found silica crystals would accumulate in the guard cells and the epidermal cells around stomates as well as in the parenchymatous cells bordering the stomatal cavity whenever adverse physiological conditions such as drouth occurred. This increase in silica was always noticed in the immediate area of the invasion focus when the plant tissue was invaded by the haustoria or mycelial tip of the rust fungus.

Noll also examined known resistant and susceptible strains of wheat, and healthy leaves of resistant strains always showed more internal silica crystal formation than was found in the susceptible strains.

The large increase in breaking strength which occurs in maize cobs of the harder genetic constitution in the last few weeks of kernel development could be explained by an increased concentration and dehydration of silicic acid or some of its derivative compounds. This could explain the positive correlation of cob weight with kernel weight which was found in all the present studies. The breaking strength variations of maize cobs could logically be explained by

variations in Si content. Hard cobs when broken and when ground in the Wiley mill have an appearance of being more crystalline on the fracture surfaces. The hard outer glumes from hard cobs are stiffer and more abrasive than those from softer cobs.

Rochow (19) has given an excellent condensed review of inorganic and organic silicon chemistry in the first few chapters of his recent book. One of the most noticeable items is the fact that for the period of 1800 to 1940 research in silicon chemistry, sporadic though it was, was chiefly concerned with hydration and dehydration phenomena and with Grignard reactions involving the fully saturated tetrahydroxide of silicon and its simple derivatives. Although quite stable in relation to the other simple silicon compounds, silicon tetrahydroxide is still extremely labile in molecular combination with itself eventually ending up in the quartz crystal lattice or combining through Grignard reactions with aliphatic or aromatic compounds. These Grignard reactions seem to have no stopping point for a few have been reported as partially autocatalytic to the extent of polymerizing simple R- and Ph- radicals from alcohols into more compound and complex aliphatic and aromatic structures, reaching an endpoint with Grignard reagent and the silicon hydroxide complex approximately in the proportions in which they entered the reaction.

The thixotropic property of silica gels makes them of special pertinence to plant physiological processes. The ease of alternation of relative liquefaction and gelation exhibited by low concentration silica gels makes these an ideal foundation structure in plant cytoplasm. Where adaptive diurnal and seasonal responses to temperature and moisture supply changes are required, silica gels in common with some of the pectinaceous materials can supply the necessary dynamic equilibrium to permit and assist other biochemical processes to be integrated into the continuing plant metabolism.

This same thixotropic property can account for the protection afforded the seed in the various seed coverings and for the rapid imbibition of water needed to initiate germination. Syneresis of the gel in the final maturation period of the seed can concentrate silicon in the seed coat where it will become beneficial in promoting imbibition when the seed is planted.

Wolff's compilation (35) along with more recent work brings out some interesting points concerning silicon in plants. Lower plants or more primitive types contain more silicon than higher forms. Monocotyledons show higher silicon contents than dicotyledons. Hydrophyls and xerophyls, at the two extremes of moisture supply, have higher silicon contents than mesophyls. Among the cereals, paddy

rice is the highest in silicon content throughout the plant, and a French patent for the use of rice hulls as an abrasive has been issued on the basis of a quoted 35.5 per cent of the dry weight of hulls as SiO_2. Radicles and plumules of germinating seed show higher proportions of SiO_2 than other portions of the seed or seedling. In general, growing tips have higher concentrations than less active growing regions. In some instances storage organs contain proportionately large amounts of silicon.

The known fact of silica gel coatings on soil particles in conditions of good tilth and optimal moisture leads to another intriguing facet in the speculation. During the period when complete ash analyses of plant tissues were being studied as a means of determining fertilizer requirements, many investigators grew young plants in flats or pots in the greenhouse using quartz sand as a medium. The usual procedure was to remove the plants, wash all visible sand particles off, dry the various portions of the plants and analyze aliquots for ash fractionations. Higher concentrations of SiO_2 were usually found in roots than in tops and the difference was attributed to poor preparation and washing of the root portions. One investigator described in detail the careful scrubbing of roots even though no sand particles were visible on close examination. Such scrubbed samples gave low SiO_2 contents in the ash.

Postulating an encapsulation of the roots with silica gel allows a homogenous colloidal continuum to exist from the soluble nutrients of the soil through the entire plant. With such a continuum able to develop the molecular arrangement of lattice attributed to the $(-O-\overset{|}{Si}-O-)_x$ nuclear complex and in view of the lability of the outer oxygen bonds of this configuration, a biochemical and biophysical framework exists for promoting polymerization reactions, while the configuration $(H_2\overset{|}{Si}-O-)_x$ is easily aminated and might be an instrumental step in protein synthesis. Mixtures of the polymerization phenomenon, which can assist in an explanation of carbohydrate syntheses, and the amination reaction in various proportions can produce a whole gamut of compounds of variable complexity and constituency such as is found upon analysis of any plant material. All of these compounds have been produced endothermically and have become energy storing materials.

The leaves of a plant, as the primary manufacturing area, are known to contain or can reasonably be suspected of containing:

1. relatively high amounts of Si,
2. chlorophyl having a molecular configuration pivoted on Mg just as the Grignard reagent is,
3. plastids of various categories, but lens shaped to facilitate focusing of radiant heat energy

into a minute rod along the focal axis of the incident beam,

4. and the available energy intensely enough concentrated at these foci to activate the synthesizing reactions which have been studied with Si compounds.

Higher Si concentrations are also found in the floral parts of the plant during active flowering and seed formation. Maize tassels have a higher content during anthesis and the ear has a still higher content at the beginning of ear formation. With the development of the cob and kernels the concentration is reduced, but the total Si content in the entire ear must be higher when the increase in mass is considered. At maturity the higher Si concentrations are in the germ and the pericarp.

Variations in Si concentration have been studied in the cereals more fully than in maize. In addition, crude ash analyses have been investigated in detail in some of the cereals during successive stages of growth as related to development and to yield. Bearded wheats have been shown, in general, to outyield beardless wheats. Rough awned barleys outyield smooth awned barleys, and these, in turn, are more prolific than hooded barleys. None of these yield comparisons was done on isoallelic stocks, but one study carried high yielding F_2 selections from a rough awned x smooth

awned barley on to F_8 and average yield of selected strains was higher for the rough awned segregates. Ash analyses always show higher concentrations in the rough awned barleys and in the bearded wheats, and other analyses show SiO_2 as one of the major components of these ashes. The barbs on awns have been found to be pure SiO_2 crystals. All of these facts correlate silicon directly and indirectly into the yield picture.

Reddy reported his pH readings from extracts of longitudinal unground halves of cobs to be the same as from the extracts of ground meal from the corresponding halves, although equilibrium was reached after a longer interval of soaking for the unground halves. This point was checked electrometrically, both with quinhydrone and glass electrode techniques, in the present study and only partial agreement with Reddy's conclusions was obtained. Extracts from samples of larger particle size took longer to reach equilibrium, but the pH reading was also at a slightly higher level. As would be expected, the more acid cobs would show higher deviations. This points to the pH reading as being a function of the number of cells fractured as well as a function of the soaking time. This, in turn, indicates the pH reading to be the result of a differential adsorption instead of an ionization of a soluble acid in the cob. A silicate complex in the cells would account for this phenomenon.

The interrelationships found for the characters studied in this research can be logically explained through the postulation of known behavior of various reactions in silicon chemistry. An investigation of some of these characters in relation to silicon concentrations may be possible with microchemical and morphological techniques similar to those used by Wagner and by Noll. It may be that one of the Si isotopes will be found radioactive and with a half-life suitable for tracer studies. The one available at present, Si^{31}, has a half-life of only 170 minutes, and its use would be limited to single or few celled algae or to some of the fungi.

Even though it may be some years before enough interest and adequate techniques are available for biochemical and biophysical studies of silicon in the higher plants, the practical breeder can still employ the easily used traits of: midcob color, breaking strength, cob weight, cob length and cob diameter to speed up the location of desirable hybrids and to select and fix those genotypes containing the desirable prepotency for yield in the hybrid progenies.

SUMMARY AND CONCLUSIONS

The maize ear characters: silking date, cob weight, cob length, cob diameter, cob breaking strength, mature cob pH, intensity of midcob color, Nigrospora resistance, and kernel weight (yield) were studied to determine amounts of interrelationship and general modes of inheritance. Four or more characters were studied simultaneously in any one year's investigation. Detailed data were collected on inbreds, single-crosses, and backcrosses over a wide range of Corn Belt dent types as well as on a few sugary and pop strains. Over 45,000 individual ears were examined in the detailed studies carried on in Iowa during the years 1930 through 1933 and 1949 through 1951. In addition, observational data on midcob color and breaking strength as related to plant vitality and yield were accumulated on over 75,000 ears of sugary and starchy maize types in Connecticut from 1933 through 1943.

The following conclusions can be drawn:

1. The inverse relationship, found by Reddy, of cob pH and Nigrospora resistance with the susceptibility threshold at pH 5.0 to 5.2 was confirmed.
2. Intensity of red midcob color expression and cob breaking strength had an inverse relationship with cob pH

although occasional inbreds were striking exceptions.

3. Breaking strength, midcob color, cob weight, cob pH, and Nigrospora resistance develop concomitantly with kernel weight and were all interrelated in varying degrees depending on genetic background.
4. Fifty to 65 per cent of the variations in yield in different groups of single crosses was attributed to variations in cob length, diameter, and weight. These three cob characters are suitable criteria for separation of desirable and undesirable yield genotypes in the early stages of a maize breeding program.
5. General and specific combining abilities, estimated by variance component analyses, were found to account for no more than 25 per cent of the yield variations. The largest source of variation was the sampling portion which consisted of the pooled variance among ears within genotypes.
6. Presence and intensity of midcob color was visually classified in two independent but not mutually exclusive series of hues: red and brown. The red series of color showed closer relationship to silking date, breaking strength, pH, and yield than did the brown series.
7. Midcob color intensity regardless of hue showed a parallel relationship with silking date, cob weight, breaking strength, and kernel weight. The highest aver-

age readings for cob weight, breaking strength, and kernel weight were found in the intermediate or less intense color class and the latest average maturity was in this same class.

8. The interrelationships of the diverse characters studied indicated a common biochemical and biophysical background. The similarity between the requirements of such a biochemical and biophysical complex and the known behavior of the $(-H_2\ Si-O-)_x$ and $(-O-\overset{|}{\underset{|}{Si}}-O-)_x$ nuclear complexes in numerous substitution and synthetic reactions was pointed out. It was postulated that these silicon complex reactions formed the foundation of the plant syntheses of carbohydrates and proteins and related compounds.

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ACKNOWLEDGMENTS

In a research study continued for such a long period, many individuals contributed advice, suggestions and criticism freely. It is a privilege to acknowledge this assistance.

The following persons deserve special mention for their encouragement during various phases of this study:

The late Dr. E. W. Lindstrom, formerly Professor and Head of the Genetics Department,

Drs. J. C. Gilman, C. S. Reddy, and F. G. Smith, Professors in the Botany Department,

Dr. M. T. Jenkins, formerly U.S.D.A. Collaborator in corn breeding at the Iowa Agricultural Experiment Station,

Dr. G. F. Sprague, Professor in the Agronomy Department,

Dr. R. M. Hixon, Dean of the Graduate College, formerly Professor in the Chemistry Department

Dr. J. W. Gowen, Professor and Head of the Genetics Department,

Dr. J. G. O'Mara, Professor in the Genetics Department,

Dr. S. N. Smith, Research Director of Michael-Leonard Seed Company, Ames, Iowa,

and F. H. Woodruff and Sons, Inc., Milford, Connecticut.

There must be added no slight encomium for help, patience, and lucid criticism, both kindly and caustic, to Grace Kopf.

APPENDIX

Table 26. Means of all characters of 54 single crosses grown in 6 locations in Iowa. 1949 crop.

Pedigree		District number[a] 7	8	9	10	11	12	Weighted means
		Average pH						
L 317	x WF 9	4.94	4.89	5.00	4.73	4.76	5.26	5.02
	B 2	5.03	5.26	5.02	4.89	4.95	5.30	5.14
	Hy	4.72	4.77	4.85	4.61	4.55	5.02	4.80
	K 155	5.09	4.78	5.25	4.76	4.83	5.43	5.14
	38-11	4.73	4.71	4.86	4.86	4.73	5.22	4.94
	B 7	5.21	5.30	5.28	4.98	5.11	5.47	5.29
	B 10	4.81	4.77	5.29	5.01	4.96	5.56	5.20
	B 13	4.76	5.06	5.05	4.78	4.69	5.56	5.04
	B 14	4.85	4.91	5.19	5.14	5.21	5.35	5.17
	B 30	4.85	5.08	5.24	4.96	4.74	5.81	5.31
WF 9	x B 2	4.58	4.87	4.79	4.68	4.30	4.85	4.69
	Hy	4.56	4.68	4.75	4.75	4.58	5.16	4.84
	K 155	4.49	4.77	4.67	4.46	4.44	4.82	4.65
	38-11	4.64	4.57	4.78	4.77	4.63	4.98	4.77
	B 7	4.74	4.98	5.10	4.89	4.75	5.08	4.93
	B 10	4.96	4.97	4.93	4.99	5.13	5.44	5.15
	B 13	4.69	4.91	4.94	4.65	4.65	5.45	4.92
	B 14	4.88	4.83	5.08	4.63	4.79	5.06	4.90
	B 30	4.70	4.91	5.16	4.88	4.45	5.23	4.92
B 2	x Hy	4.83	4.53	4.77	4.86	4.71	5.09	4.85
	K 155	4.81	4.70	4.64	4.89	4.57	4.98	4.79
	38-11	4.60	4.68	4.87	4.63	4.69	4.91	4.77
	B 7	4.74	4.97	5.12	4.67	4.56	5.19	4.96
	B 10	5.26	5.27	5.06	5.24	5.01	5.48	5.27
	B 13	5.14	5.07	4.85	4.92	4.71	5.44	5.14
	B 14	4.69	5.04	5.08	4.67	4.72	5.02	4.91
	B 30	5.03	5.00	5.11	4.91	4.99	5.44	5.14
Hy	x K 155	4.45	4.45	4.67	4.79	4.45	4.95	4.70
	38-11	4.66	4.78	4.70	4.61	4.74	5.12	4.84
	B 7	4.98	4.98	5.00	4.83	4.77	5.44	5.11
	B 10	4.85	5.06	5.04	4.92	4.93	5.18	5.04
	B 13	4.74	4.98	4.77	4.95	4.61	5.37	5.03
	B 14	4.68	4.72	4.76	4.88	4.61	5.26	4.91
	B 30	4.78	4.74	4.89	4.78	4.68	5.28	4.98

[a]See Figure 3 for district locations in Iowa.

Table 26 (continued)

Pedigree	District number 7	8	9	10	11	12	Weighted means
K 155 x B 7	4.66	4.74	4.72	4.73	4.50	5.10	4.78
B 10	4.74	4.80	4.78	4.82	4.67	5.08	4.87
B 13	4.92	5.05	5.16	5.14	4.68	5.55	5.11
B 14	4.80	4.82	4.96	5.12	4.87	5.26	5.05
B 30	4.72	4.59	4.70	4.76	4.73	5.44	4.99
38-11 x B 7	4.88	4.78	5.30	4.94	4.79	5.43	5.18
B 10	4.91	4.98	4.95	4.84	4.77	5.24	4.99
B 13	4.84	4.70	5.12	5.07	5.09	5.27	5.06
B 14	4.58	4.67	5.16	4.76	4.64	5.33	4.93
B 30	4.79	4.80	5.09	4.72	4.86	5.59	5.08
B 7 x B 10	5.21	5.51	5.51	5.28	5.18	5.75	5.49
B 13	4.96	5.22	5.34	5.01	5.07	5.49	5.27
B 14	5.20	5.10	5.35	5.15	4.98	5.46	5.26
B 30	5.19	5.11	5.79	4.84	4.99	5.75	5.38
B 10 x B 13	5.31	5.50	5.14	5.28	5.18	5.62	5.41
B 14	5.00	4.99	5.27	5.09	5.25	5.39	5.23
B 30	5.16	4.87	5.18	4.85	4.87	5.30	5.10
B 13 x B 14	4.91	4.96	5.19	5.03	4.74	5.28	5.08
B 30	4.85	4.92	5.05	5.10	4.73	5.34	5.04
B 14 x B 30	5.04	5.00	5.13	5.26	4.87	5.53	5.24
Field means	4.86	4.90	5.01	4.88	4.78	5.30	5.03

	Average cob length in cms.						
L 317 x WF 9	19.3	22.1	23.1	19.3	21.9	23.4	21.7
B 2	20.0	21.1	21.9	19.4	20.3	22.0	21.1
Hy	21.7	23.2	24.3	21.3	21.3	22.8	22.5
K 155	21.4	23.0	25.1	19.4	21.8	24.5	23.0
38-11	23.8	26.0	27.8	21.9	23.8	25.3	24.8
B 7	20.5	22.0	24.0	21.4	21.7	22.9	22.3
B 10	23.2	24.8	24.5	22.1	24.4	23.1	23.5
B 13	21.1	21.1	22.5	21.0	22.1	25.2	22.5
B 14	22.9	25.0	24.2	20.6	22.3	24.7	23.6
B 30	23.6	24.0	25.2	20.7	24.7	24.1	24.1

Table 26 (continued)

Pedigree			District number 7	8	9	10	11	12	Weighted means
			Average cob length in cms.						
WF 9	x	B 2	18.4	20.4	19.9	15.5	21.3	19.5	19.3
		Hy	18.4	19.0	20.6	15.2	19.1	18.6	18.8
		K 155	18.0	18.1	20.3	15.0	19.0	17.2	18.0
		38-11	21.8	24.2	23.4	19.2	23.2	21.8	22.4
		B 7	20.8	20.6	21.0	18.8	21.0	20.8	20.4
		B 10	20.9	20.6	21.2	18.2	20.6	19.9	20.2
		B 13	17.9	20.1	20.0	17.1	19.6	19.3	18.9
		B 14	20.0	22.1	20.8	20.3	21.6	21.2	21.1
		B 30	19.0	18.9	15.3	17.3	18.9	16.2	17.6
B 2	x	Hy	19.3	21.0	19.7	16.9	19.9	20.5	19.8
		K 155	20.1	19.2	19.9	16.4	20.5	18.6	19.0
		38-11	20.9	21.9	23.0	19.8	21.7	21.2	21.3
		B 7	18.7	21.0	20.6	18.2	20.5	19.1	19.5
		B 10	19.2	18.8	19.1	15.8	19.6	19.1	18.6
		B 13	18.9	20.4	19.6	17.6	20.2	20.4	19.7
		B 14	20.9	20.4	21.5	18.3	20.3	20.8	20.5
		B 30	20.9	21.3	20.9	19.5	20.0	21.4	20.7
Hy	x	K 155	21.0	21.1	22.0	18.7	21.2	21.7	21.2
		38-11	19.3	20.7	22.5	19.3	20.2	20.9	20.5
		B 7	20.8	21.3	21.8	19.2	20.8	21.3	21.0
		B 10	19.3	20.2	21.3	16.5	21.9	21.0	20.1
		B 13	19.8	19.2	19.2	18.8	21.6	19.3	19.6
		B 14	20.0	21.0	20.2	19.7	20.8	20.8	20.5
		B 30	19.6	21.2	21.8	17.6	20.1	21.4	20.5
K 155	x	B 7	22.5	23.5	23.9	21.8	21.6	22.6	22.6
		B 10	18.9	21.4	22.4	18.7	21.2	22.2	21.1
		B 13	18.6	20.8	22.0	19.0	20.1	20.9	20.1
		B 14	22.4	19.8	22.2	18.5	20.1	21.9	21.1
		B 30	20.1	20.9	21.8	19.0	20.7	20.5	20.5
38-11	x	B 7	23.5	24.2	25.0	21.7	24.0	23.5	23.9
		B 10	21.2	21.2	23.4	19.3	23.3	22.9	22.0
		B 13	21.4	24.3	22.7	21.5	22.4	23.4	22.9
		B 14	22.0	22.2	21.9	17.2	22.4	21.1	21.2
		B 30	21.7	22.4	23.6	19.8	23.1	22.9	22.5
B 7	x	B 10	21.0	22.9	23.5	20.0	21.7	23.5	22.5
		B 13	21.0	21.7	22.2	21.5	21.4	23.1	22.2
		B 14	21.0	22.9	20.9	20.3	22.3	22.2	21.8
		B 30	19.4	22.8	22.2	20.4	21.6	22.5	21.7

Table 26 (continued)

Pedigree			District number 7	8	9	10	11	12	Weighted means
B 10	x	B 13	17.8	19.7	24.1	18.8	20.1	21.2	20.5
		B 14	22.2	21.5	23.1	18.6	20.7	22.8	21.9
		B 30	20.6	21.7	19.0	19.9	21.7	22.5	21.3
B 13	x	B 14	18.3	19.0	20.0	17.4	20.3	19.5	19.2
		B 30	20.1	19.9	20.4	17.2	21.6	21.9	20.4
B 14	x	B 30	21.1	22.2	22.4	20.0	22.0	23.0	22.1
Field means			20.4	21.5	21.9	19.0	21.2	21.6	21.1
			Average cob diameter in mms.						
L 317	x	WF 9	23.9	24.1	24.5	23.0	24.2	24.3	23.8
		B 2	23.6	23.9	24.9	23.7	24.1	24.0	24.0
		Hy	23.8	25.0	25.3	25.0	25.5	24.3	24.7
		K 155	23.7	23.8	24.0	22.4	23.6	23.2	23.4
		38-11	24.9	24.5	23.9	24.1	24.2	23.8	24.1
		B 7	22.2	23.4	22.8	22.2	23.4	21.1	22.1
		B 10	25.4	24.9	24.0	24.5	24.5	23.5	24.2
		B 13	24.8	24.1	23.8	23.6	24.4	23.4	23.9
		B 14	21.8	21.7	21.8	21.7	21.9	21.2	21.6
		B 30	23.1	23.7	23.1	22.1	24.0	22.9	23.0
WF 9	x	B 2	23.9	25.1	24.7	23.6	25.7	25.1	24.8
		Hy	25.4	25.7	25.7	25.5	26.4	25.1	25.5
		K 155	25.2	26.0	26.9	25.4	26.9	25.2	25.8
		38-11	25.9	26.6	26.6	26.5	27.8	25.6	26.3
		B 7	25.6	24.9	26.3	25.1	26.8	25.2	25.6
		B 10	28.0	27.4	27.4	27.5	28.2	26.5	27.3
		B 13	24.4	24.5	22.8	23.7	26.6	23.7	24.2
		B 14	23.0	23.7	22.8	23.5	24.2	22.6	23.2
		B 30	24.9	25.2	24.7	23.0	26.6	23.8	24.7
B 2	x	Hy	24.7	25.2	24.7	23.9	25.9	25.2	25.0
		K 155	26.0	25.9	25.9	23.7	26.2	24.3	25.1
		38-11	26.1	25.4	24.6	25.0	26.7	24.8	25.3
		B 7	23.7	24.2	23.9	22.8	25.2	22.8	23.5
		B 10	24.4	25.3	25.6	23.9	25.7	24.3	24.8
		B 13	24.1	23.9	22.6	23.8	25.1	22.8	23.5
		B 14	23.4	23.6	23.8	22.6	23.5	22.3	23.0
		B 30	23.7	23.7	23.7	23.5	25.5	23.1	23.7

Table 26 (continued)

Pedigree			District number 7	8	9	10	11	12	Weighted means
			Average cob diameter in mms.						
Hy	x	K 155	24.9	25.2	24.6	25.0	25.8	23.9	24.7
		38-11	27.7	26.8	27.0	28.8	27.3	26.1	27.0
		B 7	25.4	24.8	25.8	26.0	26.3	25.0	25.4
		B 10	25.6	25.3	25.0	24.8	26.6	24.0	24.9
		B 13	24.0	24.7	24.1	25.2	26.0	23.8	24.5
		B 14	21.7	22.9	25.7	22.8	23.3	22.2	23.0
		B 30	22.7	24.4	24.6	23.7	25.3	24.6	24.2
K 155	x	B 7	23.4	24.4	24.5	24.4	24.9	23.3	24.0
		B 10	26.6	26.7	26.8	25.8	27.2	26.4	26.5
		B 13	21.9	22.1	23.5	22.2	23.9	22.0	22.4
		B 14	21.9	21.7	22.0	22.0	22.8	21.6	21.9
		B 30	22.7	24.1	23.8	22.4	24.6	23.3	23.4
38-11	x	B 7	26.0	25.5	24.7	25.3	27.8	24.2	25.2
		B 10	25.0	26.1	25.1	25.8	27.0	25.7	25.8
		B 13	25.0	25.9	23.5	26.0	24.6	24.4	24.7
		B 14	20.4	21.8	20.6	21.1	22.7	20.8	21.2
		B 30	22.9	24.2	23.8	22.0	24.9	23.6	23.7
B 7	x	B 10	24.5	25.3	28.2	24.8	23.3	26.0	26.1
		B 13	25.0	26.1	24.3	26.5	25.6	25.5	25.5
		B 14	22.1	23.3	23.2	23.3	24.8	22.4	23.0
		B 30	22.2	24.5	25.0	24.0	24.8	24.2	24.1
B 10	x	B 13	26.8	26.3	26.1	26.0	25.3	24.1	25.3
		B 14	22.0	24.0	22.8	22.4	23.4	22.5	22.8
		B 30	26.1	24.9	25.0	25.5	27.0	25.6	25.7
B 13	x	B 14	22.3	22.0	22.1	22.7	23.6	21.9	22.3
		B 30	25.0	24.5	23.4	23.7	25.6	24.4	24.4
B 14	x	B 30	21.8	22.7	22.0	22.9	23.1	22.4	22.5
Field means			24.1	24.5	24.4	24.0	25.2	23.8	24.2
			Average breaking strength in lbs.						
L 317	x	WF 9	148	149	160	117	151	122	136
		B 2	186	171	189	176	175	173	177

Table 26 (continued)

Pedigree			District number 7	8	9	10	11	12	Weighted means
			Average breaking strength in lbs.						
L 317	x	Hy	116	138	133	107	119	97	114
		K 155	113	145	98	82	97	81	92
		38-11	135	131	129	104	107	102	117
		B 7	104	113	102	86	98	76	92
		B 10	155	164	173	159	135	131	147
		B 13	148	147	154	129	129	127	137
		B 14	99	98	99	82	87	75	86
		B 30	116	116	117	81	112	89	100
WF 9	x	B 2	192	205	200	193	200	190	195
		Hy	140	148	149	144	128	133	139
		K 155	140	143	169	153	141	144	147
		38-11	160	138	163	133	155	125	143
		B 7	162	129	193	155	185	163	163
		B 10	189	196	201	183	197	179	188
		B 13	130	146	159	133	162	120	139
		B 14	128	137	139	120	116	127	127
		B 30	140	142	145	101	153	129	135
B 2	x	Hy	158	169	152	127	161	155	155
		K 155	174	179	197	142	167	148	164
		38-11	166	186	164	165	191	152	167
		B 7	179	183	173	172	188	144	166
		B 10	192	197	200	176	182	185	188
		B 13	196	197	191	191	198	176	187
		B 14	143	137	150	116	124	129	132
		B 30	164	175	164	143	169	140	156
Hy	x	K 155	108	109	101	87	101	86	96
		38-11	104	121	131	94	96	90	102
		B 7	119	123	124	111	103	107	112
		B 10	176	151	155	136	150	134	146
		B 13	141	139	169	124	134	127	135
		B 14	98	110	148	94	92	101	106
		B 30	98	115	105	74	81	84	90
K 155	x	B 7	103	124	118	116	110	86	107
		B 10	145	163	163	138	137	136	145
		B 13	86	94	104	73	96	81	88
		B 14	82	88	68	73	72	64	73
		B 30	90	115	105	85	92	70	87

Table 26 (continued)

Pedigree	District number 7	8	9	10	11	12	Weighted means
	Average breaking strength in lbs.						
38-11 x B 7	116	101	92	90	122	68	88
B 10	150	142	156	150	159	132	146
B 13	154	190	144	140	96	130	141
B 14	81	100	82	80	93	81	86
B 30	94	102	96	65	89	82	89
B 7 x B 10	156	125	176	147	157	148	150
B 13	144	147	146	146	143	135	141
B 14	106	114	102	94	96	85	96
B 30	80	120	92	94	87	86	90
B 10 x B 13	194	196	152	194	181	173	179
B 14	113	142	125	114	106	111	117
B 30	167	154	152	150	151	162	157
B 13 x B 14	134	138	142	118	131	122	128
B 30	151	159	137	139	137	141	145
B 14 x B 30	97	106	100	86	88	80	89
Field means	136	142	143	125	132	120	130

Table 27. SN3 hybrids. Means for all characters of 200 single crosses. 1951 crop.

Pedigree ♀	Pedigree ♂	No. of ears	Characters S[a] days	C gms.	L cms.	D mms.	B lbs.	K gms.
A	P	29	6.14	23.62	20.10	18.97	51.69	133.59
P	A	29	4.76	25.21	19.97	19.55	56.38	140.21
A	Y	27	5.70	26.26	20.00	20.67	60.26	149.04
Y	A	30	6.70	27.47	20.73	20.43	58.27	162.93
A	E	28	4.97	22.79	19.54	19.64	44.82	138.57
E	A	27	5.30	23.52	19.74	19.81	47.89	141.33
A	U	28	4.68	22.64	18.00	21.75	46.57	119.00
U	A	30	2.60	24.80	17.87	23.10	56.93	127.13
A	L	29	8.59	26.86	17.97	22.90	78.10	135.93
L	A	29	8.03	27.62	18.28	23.07	89.62	142.14
A	H	23	8.61	36.30	20.87	23.74	68.22	159.43
H	A	30	8.70	33.47	20.47	23.57	79.77	161.00
A	I	26	7.88	29.84	20.27	22.50	74.11	175.69
I	A	24	8.54	31.75	19.17	23.38	83.13	170.33
A	M	28	8.61	29.21	21.46	20.96	59.36	161.86
M	A	26	9.38	32.23	22.46	21.61	63.46	173.30
A	B	27	7.19	30.48	19.15	20.26	99.96	167.93
B	A	27	9.85	29.81	18.19	19.81	98.41	157.70
A	G	27	11.26	32.11	21.07	20.41	73.81	154.74
G	A	29	12.79	33.21	21.03	20.28	76.45	157.31
A	D	24	9.54	30.17	20.67	22.38	70.54	180.75
D	A	27	10.96	30.41	21.52	22.89	56.26	173.33
A	K	30	10.03	27.73	21.37	20.93	58.73	157.00
K	A	30	9.10	30.80	22.27	21.10	63.37	178.33
A	V	22	10.86	31.45	20.00	22.18	72.46	166.55
V	A	29	9.97	31.14	20.00	22.55	73.55	168.86

[a]S = silking date (days from 26 July 1951), C = cob weight, L = cob length, D = cob diameter, B = breaking strength, K = kernel weight.

Table 27 (continued)

Pedigree ♀	Pedigree ♂	No. of ears	Characters S days	C gms.	L cms.	D mms.	B lbs.	K gms.
A	W	25	11.76	29.48	19.32	20.44	85.64	135.12
W	A	28	9.89	29.36	19.79	19.97	77.32	138.71
P	Y	30	8.33	23.07	19.50	19.30	57.63	145.77
Y	P	25	9.92	22.84	20.04	19.12	63.12	163.72
P	E	29	8.62	20.72	20.45	17.79	42.62	150.62
E	P	26	9.35	20.54	20.81	18.08	44.38	140.65
P	U	29	7.86	25.69	20.24	21.07	47.97	157.10
U	P	25	6.56	27.08	20.20	21.20	50.24	162.52
P	L	29	8.79	31.62	19.93	22.34	90.52	155.17
L	P	28	8.39	32.21	20.18	22.54	95.50	168.28
P	H	26	8.24	33.00	21.19	23.38	81.42	190.03
H	P	28	8.68	35.64	21.96	22.32	81.96	183.71
P	I	24	10.54	34.08	21.50	22.96	93.79	186.67
I	P	25	10.20	31.96	21.56	21.60	88.80	178.60
P	M	30	9.93	29.87	23.40	21.07	60.83	185.93
M	P	33	10.33	30.76	23.76	20.79	59.00	185.39
P	B	30	7.37	28.60	18.07	19.13	92.20	173.56
B	P	26	10.85	26.77	18.58	18.73	78.04	167.65
P	G	26	11.19	33.54	22.00	22.31	86.54	204.72
G	P	20	14.80	28.80	21.20	20.85	82.95	172.30
P	D	28	10.89	37.36	22.07	22.39	88.11	220.50
D	P	25	12.84	26.04	21.84	21.96	51.08	189.16
P	K	29	11.24	30.10	23.34	21.24	64.86	179.14
K	P	26	10.09	29.38	22.77	20.42	59.54	171.38
P	V	26	12.19	34.54	21.81	22.27	82.61	191.07
V	P	32	10.66	33.25	21.97	21.44	75.88	200.50
P	W	28	11.46	27.36	20.68	20.29	79.57	152.64
W	P	26	12.35	27.08	20.38	21.04	75.46	147.80

Table 27 (continued)

Pedigree ♀	Pedigree ♂	No. of ears	Characters S days	C gms.	L cms.	D mms.	B lbs.	K gms.
Y	E	21	10.62	16.71	17.43	17.71	34.86	124.00
E	Y	22	11.14	15.82	16.73	17.68	30.64	106.00
Y	U	27	8.22	29.67	20.44	21.56	46.93	171.19
U	Y	29	6.10	29.28	20.72	21.17	46.76	171.28
Y	L	27	10.15	33.22	20.07	22.19	97.11	175.41
L	Y	29	8.21	30.79	19.79	22.41	89.93	177.73
Y	H	28	9.14	37.21	20.86	24.50	77.39	202.78
H	Y	27	10.74	38.26	20.59	25.78	88.15	213.26
Y	I	30	11.80	39.80	21.27	23.53	93.57	216.26
I	Y	30	8.93	31.40	19.63	22.40	82.37	204.26
Y	M	29	9.66	34.31	21.10	22.79	70.93	193.90
M	Y	30	10.10	34.53	21.53	21.90	67.37	194.20
Y	B	28	9.54	35.43	19.86	21.29	104.50	196.14
B	Y	28	9.25	32.21	19.93	21.50	93.14	193.14
Y	G	29	12.62	34.66	22.59	21.17	78.97	207.66
G	Y	26	15.88	33.77	21.88	21.65	82.27	204.92
Y	D	29	14.03	31.21	21.17	22.79	63.14	214.42
D	Y	29	14.21	27.55	21.62	22.00	44.14	201.66
Y	K	28	11.29	32.43	22.71	21.21	70.96	192.03
K	Y	26	12.15	31.08	22.38	21.27	66.92	191.26
Y	V	27	13.52	33.00	20.70	22.33	66.63	209.04
V	Y	30	11.17	35.00	21.00	22.90	71.77	222.06
Y	W	29	11.93	25.67	20.31	19.28	70.38	156.62
W	Y	28	13.18	25.14	19.46	20.46	80.86	158.96
E	U	29	7.90	24.03	19.72	21.59	36.14	142.55
U	E	23	5.00	24.22	19.26	21.87	36.26	140.22
E	L	25	8.64	28.92	20.96	22.20	61.56	168.56
L	E	26	10.31	26.85	20.50	21.61	58.84	168.00

Table 27 (continued)

Pedigree ♀	Pedigree ♂	No. of ears	Characters S days	C gms.	L cms.	D mms.	B lbs.	K gms.
E	H	34	8.38	30.35	20.74	21.62	52.82	181.59
H	E	27	7.15	32.33	20.78	22.70	58.07	190.96
E	I	27	10.15	26.63	19.96	21.26	51.56	179.81
I	E	28	9.43	29.07	20.93	21.86	50.43	196.86
E	M	27	9.67	26.93	20.48	20.22	49.89	166.37
M	E	29	9.03	27.76	20.52	20.34	54.10	160.83
E	B	27	6.89	31.81	20.26	20.93	87.44	183.04
B	E	27	9.22	29.74	20.11	20.81	77.59	176.37
E	G	27	11.52	31.07	22.48	21.00	64.48	185.41
G	E	26	15.74	28.85	21.54	20.96	60.27	173.38
E	D	24	11.67	32.83	21.08	22.92	67.00	210.84
D	E	29	11.97	26.72	21.93	21.76	39.10	194.31
E	K	29	9.24	27.00	21.38	20.66	50.24	190.00
K	E	30	11.13	24.47	20.73	20.47	47.53	173.10
E	V	26	10.61	35.00	20.61	23.38	67.46	216.11
V	E	27	10.56	30.78	20.56	22.04	57.33	200.85
E	W	29	11.52	24.66	20.55	19.45	58.28	154.45
W	E	23	12.22	25.78	21.35	19.13	61.26	156.39
U	L	28	9.71	33.36	18.68	25.11	84.18	147.14
L	U	28	8.00	34.36	19.29	25.54	77.25	156.78
U	H	28	6.79	39.86	20.89	26.07	69.64	181.64
H	U	28	7.32	41.86	21.39	25.89	70.11	185.64
U	I	26	7.65	40.84	20.19	25.81	81.92	182.22
I	U	22	7.23	40.09	20.59	26.86	78.82	189.46
U	M	28	8.00	34.64	21.14	24.14	54.57	167.14
M	U	29	7.45	33.97	21.07	23.93	52.69	164.76
U	B	28	8.14	34.71	18.57	22.29	88.46	172.64
B	U	28	9.21	35.86	18.93	23.00	88.00	186.14

Table 27 (continued)

Pedigree ♀	Pedigree ♂	No. of ears	Characters S days	C gms.	L cms.	D mms.	B lbs.	K gms.
U	G	28	10.18	39.50	20.82	24.14	71.11	171.57
G	U	27	13.08	35.30	19.48	23.63	64.15	166.07
U	D	28	9.96	37.43	20.29	25.89	67.43	189.14
D	U	28	11.43	32.86	20.36	25.54	46.04	182.07
U	K	28	8.11	34.29	22.32	23.71	61.11	178.14
K	U	30	8.93	30.13	21.67	22.80	48.50	170.86
U	V	29	9.62	37.28	20.41	24.24	62.35	195.24
V	U	28	9.39	36.43	20.07	24.04	61.57	193.28
L	H	32	9.56	45.31	17.88	28.09	139.38	172.62
H	L	28	11.04	45.14	19.54	26.79	116.00	188.93
L	I	24	13.21	43.33	18.92	26.42	151.50	195.17
I	L	27	11.93	40.22	21.04	25.15	85.93	203.67
L	M	24	10.67	39.50	20.92	24.21	96.33	198.71
M	L	27	10.70	35.59	20.67	23.89	83.85	182.44
L	B	27	10.81	42.70	17.48	24.63	174.07	181.33
B	L	29	11.10	45.00	17.55	25.07	183.90	184.28
L	G	29	14.52	40.86	19.62	23.24	123.31	184.00
G	L	29	16.31	42.79	19.07	23.86	131.76	191.10
L	D	27	13.63	32.04	19.30	25.22	74.74	187.18
D	L	27	11.56	34.78	20.52	26.22	80.07	202.67
L	K	29	11.83	38.59	20.83	24.38	97.38	195.93
K	L	30	10.73	40.53	20.87	24.30	99.73	203.33
L	V	27	12.93	41.52	18.52	25.70	135.96	201.18
V	L	29	10.38	40.79	18.83	25.93	141.76	203.45
H	I	28	11.64	44.57	20.18	28.00	105.07	221.28
I	H	24	13.67	39.92	17.29	25.92	140.21	169.42
H	M	29	10.28	38.45	21.48	25.62	73.21	207.93
M	H	29	12.10	38.59	22.07	26.31	65.28	209.66

Table 27 (continued)

Pedigree ♀	Pedigree ♂	No. of ears	Characters S days	C gms.	L cms.	D mms.	B lbs.	K gms.
H	B	26	9.50	46.00	19.92	25.15	131.46	208.45
B	H	29	11.21	38.24	19.62	23.41	112.76	200.42
H	G	29	14.97	44.86	21.59	25.93	114.97	208.14
G	H	29	15.93	47.48	22.10	25.76	103.00	232.21
H	D	25	12.20	45.00	21.72	27.60	98.60	242.64
D	H	29	12.41	36.03	20.38	26.72	71.21	212.35
H	K	30	11.67	38.93	22.30	24.83	79.33	214.53
K	H	29	11.52	36.59	22.79	24.59	67.45	214.90
H	V	27	12.81	48.93	21.22	27.07	110.30	234.37
V	H	29	11.83	43.83	21.10	26.41	94.38	221.59
I	M	27	10.96	43.74	21.30	26.04	95.44	199.11
M	I	29	12.04	39.55	21.45	24.93	82.48	201.45
I	B	26	11.19	40.65	19.19	23.35	148.88	204.65
B	I	30	11.20	41.60	19.67	23.17	142.07	204.73
I	G	21	15.14	45.67	21.76	23.90	126.90	227.90
G	I	29	17.66	46.45	21.52	25.00	130.38	220.48
I	D	30	13.93	38.40	20.70	27.23	86.30	212.66
D	I	28	14.07	40.43	20.96	27.25	86.54	221.93
I	K	26	14.58	39.84	21.38	24.15	103.53	224.45
K	I	27	14.00	38.48	21.67	24.48	99.81	222.67
I	V	29	13.52	41.83	19.17	25.55	124.55	223.38
V	I	28	12.47	43.57	20.14	25.07	121.14	241.64
M	B	28	10.39	43.64	21.14	23.18	113.96	206.86
B	M	26	12.19	41.77	20.38	22.92	106.65	209.91
M	G	28	15.14	38.50	21.36	22.11	85.75	187.21
G	M	25	15.96	37.16	20.92	22.56	86.72	191.12
M	D	29	13.45	35.69	21.28	25.10	68.35	224.07
D	M	29	12.62	35.55	21.97	25.03	62.35	228.14

Table 27 (continued)

Pedigree ♀	Pedigree ♂	No. of ears	Characters S days	C gms.	L cms.	D mms.	B lbs.	K gms.
M	K	30	12.30	36.00	23.23	22.67	59.93	201.93
K	M	29	11.21	36.93	23.28	22.41	61.45	204.83
M	V	28	14.54	38.36	21.54	24.71	65.79	219.64
V	M	30	12.07	38.60	22.07	24.30	62.73	211.20
B	G	28	15.96	39.86	19.39	22.50	130.36	197.64
G	B	26	16.92	45.08	20.19	23.54	147.72	221.07
B	D	30	13.47	37.53	20.77	24.60	84.53	230.26
D	B	28	14.07	35.50	20.21	24.18	88.93	217.71
B	K	28	13.54	41.00	21.57	22.79	108.11	224.36
K	B	28	10.71	39.29	21.61	21.86	97.61	222.14
B	V	29	11.55	44.38	20.38	23.21	144.90	209.86
V	B	29	13.07	41.14	19.55	23.10	137.86	199.10
G	D	25	20.08	30.76	19.64	23.12	61.48	170.00
D	G	23	20.65	31.00	20.35	23.43	63.74	174.35
G	K	25	17.56	37.56	22.36	22.24	93.16	195.20
K	G	29	15.00	39.62	22.93	21.86	94.38	189.10
G	V	25	17.84	38.68	20.20	23.08	99.20	203.20
V	G	29	15.17	37.48	20.34	22.83	87.66	209.86
D	K	27	14.00	33.22	22.67	24.41	65.85	235.93
K	D	29	14.28	31.62	21.79	24.10	65.83	226.69
D	V	28	13.75	35.07	21.29	24.68	58.50	221.07
V	D	29	13.24	33.76	21.31	24.31	53.45	215.79
K	V	29	12.69	42.24	22.73	24.03	90.83	216.00
V	K	29	12.45	42.45	22.73	24.34	90.28	219.17
U	W	29	10.69	29.90	18.24	22.55	85.35	136.55
L	W	28	12.54	33.64	18.07	23.36	122.75	159.64
H	W	27	12.00	43.37	21.15	24.70	132.19	189.56
I	W	24	12.13	40.92	19.04	25.46	147.96	200.25
H	W	28	13.61	32.86	19.86	22.50	79.96	177.36
B	W	27	13.04	36.11	18.19	21.93	150.52	165.11
G	W	22	19.45	35.55	19.00	22.09	127.82	162.91
D	W	27	10.26	32.56	20.85	23.07	61.48	180.67
K	W	28	14.61	29.71	19.07	22.11	92.75	169.14
V	W	29	14.59	34.17	17.83	23.76	122.86	187.04

Table 28. North Central hybrids. Means for all characters of 66 single crosses. 1951 crop.

Pedigree	No. of ears	Character B[a] days	C gms.	L cms.	D mms.	B lbs.	K gms.
WF 9 x Hy	29	13.03	46.24	20.07	25.79	115.69	244.35
B 7	29	13.69	47.69	21.83	26.21	150.04	221.66
I 205	24	9.63	34.67	18.83	24.46	106.67	215.00
Os 420	25	11.68	45.72	21.92	26.20	133.56	243.60
187-2	26	13.50	45.77	22.50	24.65	130.03	230.45
B 23	25	13.04	45.48	22.20	23.44	118.12	234.32
B 24	26	12.42	39.46	21.50	23.00	97.42	225.84
M 14	26	10.85	44.46	20.96	25.85	102.88	232.14
Oh 28	30	12.33	51.93	22.57	25.37	117.73	268.33
W 22	29	11.24	48.86	20.66	25.69	153.83	255.17
B 25	28	12.25	45.14	21.07	25.89	163.05	244.11
Hy x B 7	29	14.79	48.04	21.59	26.41	110.17	236.97
I 205	23	13.48	39.00	19.65	24.96	94.87	227.75
Os 420	29	13.03	46.93	20.86	26.79	115.62	253.52
187-2	26	15.92	44.84	20.61	24.69	82.43	254.84
B 23	32	15.09	49.63	22.88	25.75	110.88	257.81
B 24	24	16.38	28.33	17.50	22.58	64.63	154.25
M 14	25	13.16	45.48	22.72	26.44	86.96	239.36
Oh 28	25	13.76	48.20	21.92	26.32	106.88	260.08
W 22	27	14.96	48.04	21.00	25.96	118.63	252.81
B 25	28	14.11	45.49	19.96	25.83	120.52	242.54
B 7 x I 205	23	15.96	37.44	18.45	23.48	107.00	186.36
Os 420	28	13.89	48.57	22.96	25.75	127.73	254.97
187-2	27	15.44	42.78	23.04	24.07	99.44	228.81
B 23	26	16.77	50.92	22.31	25.38	109.15	249.92
B 24	29	12.73	40.72	21.79	23.00	81.76	219.04
M 14	21	10.43	43.38	21.62	25.57	76.05	226.76
Oh 28	27	16.30	49.44	23.15	25.93	99.48	242.81
W 22	28	16.68	45.57	21.14	25.93	127.23	231.12
B 25	29	15.52	41.14	21.17	26.07	124.66	206.69
I 205x Os 420	22	10.32	40.36	20.82	26.05	113.18	243.37
187-2	24	14.71	32.17	19.33	22.38	73.00	191.75
B 23	26	13.85	46.77	21.04	24.88	111.30	223.45
B 24	24	11.83	38.08	20.63	23.96	104.33	218.17
M 14	27	12.30	31.07	19.11	24.48	77.44	205.04
Oh 28	25	13.64	43.32	20.76	24.88	98.56	237.92
W 22	28	12.03	42.78	19.26	26.07	144.95	234.04
B 25	18	10.28	40.78	19.22	25.22	135.56	216.45

[a]See Table 27 for explanation of characters.

Table 28 (continued)

Pedigree	No. of ears	Character S days	C gms.	L cms.	D mms.	B lbs.	K gms.
Os 420x 187-2	30	15.40	39.73	22.63	23.57	81.40	226.33
B 23	24	13.50	48.83	23.25	25.75	115.33	267.00
B 24	24	12.00	40.58	21.29	23.88	82.54	222.59
M 14	29	13.21	42.10	23.17	25.62	86.55	250.48
Oh 28	24	15.04	42.50	21.79	24.46	84.33	219.50
W 22	28	14.53	41.92	21.43	25.53	110.24	241.19
B 25	28	13.18	39.85	20.60	24.75	103.81	232.47
187-2 x B 23	27	14.74	40.33	21.67	23.48	67.07	205.11
B 24	23	13.57	41.44	21.96	22.39	70.26	214.88
M 14	25	12.56	43.08	23.20	24.04	68.08	230.32
Oh 28	28	16.68	41.71	21.82	23.46	78.95	220.62
W 22	27	14.33	39.96	21.48	23.89	92.07	208.30
B 25	27	14.89	39.67	20.74	23.59	106.56	218.32
B 23 x B 24	23	13.22	42.74	22.22	23.00	83.31	216.00
M 14	29	12.76	47.62	22.59	25.24	93.42	212.14
Oh 28	28	14.50	49.71	23.89	24.57	88.31	250.76
W 22	28	12.11	46.07	21.10	25.65	126.02	240.83
B 25	29	14.07	46.66	22.00	25.21	127.38	235.38
B 24 x M 14	29	8.93	40.93	22.21	24.00	78.76	209.17
Oh 28	25	13.52	43.08	22.52	23.56	70.24	239.12
W 22	23	10.57	39.35	21.48	22.74	83.00	227.49
B 25	26	13.08	42.46	21.85	23.50	102.80	228.22
M 14 x Oh 28	26	13.65	41.15	22.69	24.31	68.15	231.14
W 22	27	12.78	40.41	22.07	24.70	89.11	231.15
B 25	30	12.83	46.53	22.73	26.37	106.83	243.46
Oh 28 x W 22	28	15.61	44.64	21.39	26.14	116.63	246.48
B 25	31	15.94	45.90	21.52	25.39	117.48	233.61
W 22 x B 25	28	13.68	48.57	21.00	27.35	149.77	267.40

Table 29. South Central hybrids. Means for all characters of 65 single crosses. 1951 crop.

Pedigree	No. of ears	Characters Sa days	C gms.	L cms.	D mms.	B lbs.	K gms.
L 317 x WF 9	26	17.00	46.46	21.81	24.08	129.96	207.99
B 2	26	16.08	50.92	21.31	22.77	139.93	238.53
Hy	26	17.35	47.92	22.11	25.50	117.73	234.00
K 155	22	21.32	40.45	22.55	24.27	90.64	187.18
38-11	26	20.58	44.09	23.15	23.69	99.61	190.92
B 7	20	18.95	38.80	22.70	23.30	86.30	173.80
B 10	27	21.07	51.30	24.48	25.22	141.52	205.11
B 13	26	19.77	43.00	21.11	25.50	151.76	200.76
B 14	25	16.40	45.32	23.40	22.44	99.24	217.52
B 18	25	19.68	35.40	23.00	22.76	74.48	190.16
B 30	26	16.96	47.84	24.08	23.35	107.00	211.91
WF 9 x B 2	29	13.97	54.38	20.41	23.52	186.93	240.97
Hy	29	13.03	46.24	20.07	25.79	115.69	244.35
K 155	30	16.07	40.93	18.57	25.60	123.97	204.33
38-11	28	14.82	44.07	22.32	26.36	120.11	241.28
B 7	29	13.69	47.69	21.83	26.21	150.04	221.66
B 10	26	17.00	51.31	21.65	26.31	133.80	241.30
B 13	27	15.85	50.04	19.67	27.26	187.85	248.96
B 14	30	12.37	50.40	22.60	23.83	155.50	245.83
B 18	27	16.85	44.26	23.15	24.15	92.22	271.48
B 30	27	14.37	34.41	18.19	23.59	108.07	156.59
B 2 x Hy	29	14.83	47.76	18.83	23.90	141.59	219.59
K 155	29	17.10	52.31	19.31	25.62	168.79	237.45
38-11	27	17.56	63.08	21.33	25.70	198.67	246.52
B 7	26	14.92	55.15	20.31	23.96	162.76	247.53
B 10	24	17.88	73.58	22.25	25.71	198.21	278.84
B 13	27	15.93	56.63	20.78	24.26	197.78	239.26
B 14	26	15.92	45.84	19.69	22.50	153.96	202.45
B 18	28	20.25	46.93	22.04	21.89	113.21	238.57
B 30	21	13.57	54.81	21.38	25.67	178.10	246.95
Hy x K 155	22	18.95	45.91	20.68	25.86	99.82	235.73
38-11	21	18.10	48.71	22.33	28.05	132.90	269.43
B 7	29	14.80	48.03	21.59	26.41	110.17	236.97
B 10	25	17.76	60.76	22.80	28.00	161.44	271.36
B 13	27	17.56	45.30	20.33	27.04	145.48	249.41
B 14	28	15.86	46.21	21.39	23.68	109.03	251.93
B 18	28	19.50	41.50	21.93	25.11	81.89	246.78
B 30	25	15.88	43.56	21.52	25.44	88.56	244.16

[a]See Table 27 for explanation of characters.

Table 29 (continued)

Pedigree	No. of ears	Characters S days	C gms.	L cms.	D mms.	B lbs.	K gms.
K 155 x 38-11	22	19.23	49.18	23.00	27.36	126.36	242.73
B 10	27	15.48	40.70	22.78	22.00	76.81	233.04
B 13	31	15.29	38.81	20.84	23.77	81.23	220.39
B 14	25	19.20	35.00	21.36	22.12	67.00	214.08
B 18	23	22.00	45.09	22.52	24.48	89.91	236.69
B 30	29	18.59	42.17	20.97	24.76	94.86	237.73
38-11 x B 7	27	18.93	43.74	24.11	27.15	86.85	231.18
B 10	23	22.13	63.09	24.91	29.35	166.78	245.56
B 13	25	21.48	47.08	22.48	27.60	163.76	234.32
B 14	25	14.80	48.68	24.12	23.92	141.88	251.52
B 18	25	21.20	45.32	25.64	27.72	92.24	248.72
B 30	20	20.00	32.60	21.15	23.55	66.60	182.10
B 7 x B 10	25	19.08	58.92	25.88	26.60	119.88	254.24
B 13	27	18.19	43.89	21.15	27.04	163.15	210.52
B 14	29	16.62	43.21	22.48	23.69	114.04	220.90
B 18	26	19.08	40.62	23.96	24.31	74.61	245.00
B 30	28	15.32	47.64	24.00	25.43	94.61	240.00
B 10 x B 13	22	22.23	57.09	21.32	27.59	183.55	211.73
B 14	30	18.97	50.40	23.03	23.73	123.50	220.96
B 18	25	23.80	60.84	25.52	26.80	137.80	270.88
B 30	23	20.26	57.87	23.35	26.74	119.26	241.82
B 13 x B 14	23	17.96	44.83	20.70	23.96	147.13	223.39
B 18	25	21.12	42.36	22.36	25.76	126.00	233.56
B 30	23	18.43	48.30	20.43	26.13	153.00	222.52
B 14 x B 18	29	18.52	46.03	24.93	22.41	95.83	267.11
B 30	24	16.17	44.25	23.00	22.79	92.88	236.84
B 18 x B 30	25	19.40	42.60	23.08	25.16	82.32	231.20

Table 30. Comparisons of means of characters of inbreds and their single cross progenies. 3NS group. 1951 data.

Inbred	Progeny group	No. of ears	Character S[a] days	C gms.	L cms.	D mms.	B lbs.	K gms.
A	I[b]	25	9.68	16.84	15.16	18.64	49.52	59.36
	H	768	8.25	28.81	20.04	21.36	68.49	154.07
P	I	23	12.00	15.26	16.83	18.13	35.87	62.39
	H	767	9.64	28.95	21.07	20.84	70.50	171.21
Y	I	29	12.79	16.38	16.00	19.41	39.27	102.20
	H	778	10.48	30.54	20.56	21.54	70.57	184.18
E	I	25	11.04	14.44	17.04	18.00	19.76	89.04
	H	752	9.53	26.77	20.45	20.73	53.42	169.13
U	I	29	9.58	17.55	13.93	21.34	23.31	63.65
	H	748	8.16	32.92	20.03	23.63	62.21	166.77
L	I	27	19.87	17.80	10.92	23.61	81.96	60.09
	H	751	10.81	36.65	19.43	24.32	106.35	178.67
H	I	25	11.36	50.12	20.24	30.12	75.12	178.72
	H	758	10.66	39.92	20.83	25.27	91.54	199.98
I	I	19	16.53	31.21	16.21	23.58	87.52	107.47
	H	719	11.73	38.68	20.40	24.56	101.67	203.46
M	I	30	17.06	21.00	17.16	20.86	33.76	91.59
	H	764	11.18	35.65	21.58	23.18	71.41	193.26
B	I	29	17.58	22.86	14.38	20.38	125.75	86.13
	H	750	11.01	37.60	19.57	22.47	115.25	195.07

[a]S = silking date (days from 26 July 1951), C = cob weight, L = cob length, D = cob diameter, B = breaking strength, K = kernel weight.

[b]I = inbred, H = hybrid.

Table 30 (continued)

Inbred	Progeny group	No. of ears	Character S days	C gms.	L cms.	D mms.	B lbs.	K gms.
G	I	22	24.68	20.19	16.18	20.18	75.63	77.36
	H	716	15.22	37.60	20.99	22.75	94.56	191.57
D	I	22	22.18	14.45	14.50	20.91	10.41	79.00
	H	730	13.18	33.80	21.07	24.37	67.55	206.95
K	I	27	19.20	17.72	17.58	19.54	30.82	85.03
	H	768	11.96	34.79	22.02	22.72	75.98	198.36
V	I	28	20.10	22.07	13.03	23.25	99.38	73.99
	H	759	12.33	38.00	20.61	23.92	77.13	207.77
[illegible]	I	21	25.19	10.72	10.58	19.95	66.43	28.86
	H	474	12.64	31.11	19.59	21.71	95.18	162.14
Means	I	381	16.38	20.53	15.32	21.19	59.27	84.10
	H	5512	11.05	34.16	20.58	22.91	81.84	185.95

Table 31. Comparisons of means of characters of inbreds and their single cross progenies. North Central group. 1951 data.

Inbred	Progeny group	No. of ears	Character S[a] days	C gms.	L cms.	D mms.	B lbs.	K gms.
WF 9	I[b]	26	17.84	24.38	14.73	23.61	106.00	97.84
	H	297	12.19	45.28	21.30	25.18	126.96	238.41
Hy	I	20	20.60	21.30	15.00	24.20	38.95	100.90
	H	297	14.33	44.91	20.86	25.64	103.54	239.83
B 7	I	24	24.75	25.00	16.63	24.88	72.84	59.08
	H	296	14.80	45.18	21.77	25.28	111.28	228.17
I 205	I	16	18.38	19.12	11.50	24.94	105.06	66.62
	H	264	12.60	38.77	19.74	24.62	105.67	218.26
Os 420	I	24	19.96	24.34	15.67	24.34	69.55	87.34
	H	291	13.33	43.37	21.90	25.30	97.03	241.48
187-2	I	23	22.65	17.70	16.26	30.13	24.65	67.96
	H	290	14.75	41.08	21.75	23.68	86.57	221.10
B 23	I	15	23.00	19.00	15.40	20.47	30.80	79.20
	H	297	13.99	46.89	22.29	24.80	104.82	235.94
B 24	I	22	17.04	17.36	15.41	19.95	24.77	88.81
	H	276	12.51	39.80	21.38	23.25	83.67	216.03
M 14	I	29	15.17	24.10	17.90	23.62	35.15	99.03
	H	294	12.15	42.40	22.12	25.18	85.46	228.28
Oh 28	I	25	21.64	23.96	17.00	23.20	41.16	77.60
	H	297	14.66	45.73	22.19	24.96	95.95	241.27
W 22	I	27	19.13	20.46	14.76	22.05	58.31	86.88
	H	301	13.54	44.31	21.08	25.48	120.14	239.99
B 25	I	26	21.77	19.08	13.73	22.46	89.38	65.30
	H	302	13.75	44.00	21.16	25.41	123.14	234.15
Means	I	277	20.03	21.56	15.47	22.86	59.04	81.97
	H	1751	13.56	43.55	21.48	24.91	104.53	232.16

[a]See Table 30 for explanation of characters.

[b]See Table 30 for explanation of symbols.

Table 32. Comparisons of means of characters of inbreds and their single cross progenies. South Central group. 1951 data.

Inbred	Progeny group	No. of ears	Character Sa days	C gms.	L cms.	D mms.	B lbs.	K gms.
L 317	I[b]	22	26.27	22.36	18.22	20.72	58.77	60.90
	H	275	18.62	44.93	22.71	23.92	113.75	206.23
WF 9	I	26	17.84	24.38	14.73	23.61	106.00	97.84
	H	308	14.94	46.40	20.92	25.15	137.05	229.63
B 2	I	29	19.34	35.07	14.07	24.27	196.02	113.85
	H	292	16.22	54.42	20.65	24.10	166.66	239.10
Hy	I	20	20.60	21.30	15.00	24.20	38.95	100.90
	H	289	16.57	47.35	21.19	25.81	118.44	245.12
K 155	I	6	28.50	19.00	13.67	22.33	61.84	55.00
	H	260	18.09	42.94	21.13	24.54	102.58	224.90
38-11	I	23	27.26	28.48	18.74	26.18	66.66	79.31
	H	269	18.90	48.32	23.16	26.39	127.69	235.20
B 7	I	24	24.75	25.00	16.63	24.88	72.84	59.09
	H	266	16.84	46.87	22.77	25.47	117.09	229.29
B 10	I	21	28.72	47.19	22.06	25.82	158.25	101.05
	H	277	19.52	56.49	23.46	26.06	140.55	242.62
B 13	I	13	25.54	17.01	11.23	24.46	111.53	58.15
	H	283	18.38	46.80	21.00	25.95	153.34	227.08
B 14	I	19	20.68	26.58	17.42	21.05	109.85	20.21
	H	294	16.59	45.63	22.47	23.19	118.46	232.56
B 18	I	16	30.94	20.25	18.06	21.44	28.19	86.00
	H	286	20.06	44.62	23.46	24.54	96.37	244.21
B 30	I	28	21.21	23.50	17.43	21.36	69.21	82.78
	H	271	17.13	44.99	21.93	24.75	106.77	222.98
Means	I	247	23.58	26.87	16.68	23.45	96.13	85.64
	H	1685	17.62	47.51	22.05	24.98	125.28	231.73

[a]See Table 30 for explanation of characters.

[b]See Table 30 for explanation of symbols.